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CHANGES IN HORNBLENDE AT ABOUT 800°C.

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INTRODUCTION

In recent years much activity has been displayed in the study of the amphiboles and repeatedly the problem connected with the change on heating of common hornblende to a material having the appearance and optical properties of basaltic hornblende has been attacked and partially solved. The purpose of this paper is to solve the problem definitely. The writer wishes to acknowledge the helpful guidance by Dr. A. N. Winchell and the suggestions on optical methods offered by Dr. R. C. Emmons, and is also deeply indebted to the Canadian Geological Survey for the sample of analyzed edenite from Argenteuil County, Quebec, and to the Milwaukee Museum for a sample of actinolite from Val Malenco, Italy.

HISTORICAL REVIEW

It has been known for nearly 50 years that common hornblende when heated to a sufficiently high temperature takes on the properties of basaltic hornblende; namely, a change in color and pleochroism from greens to browns, an increase in absorption, an increase in double refraction and a decrease in the extinction angle ($Z \wedge c$) from about 20° to 0°.

Rosenbusch[1] in 1885 noted that a dark green hornblende with little pleochroism when heated became red and had strong absorption.

Schneider[2] in 1891 studied a series of basaltic hornblendes and found that upon heating them in superheated steam he obtained a change in extinction angle to near 0°, and an increase in pleochroism and absorption. The ferrous iron content and the extinction angle of the unheated hornblendes taken presumably on the prism (110) face, are given in Table I. He did not give the ferrous iron content after heating, but said that practically none is present and that the extinction angle has been reduced to 0°, and that the pleochroism and absorption have increased except in the last two samples which already had strong pleochroism and absorption. He believed that volcanic steam converted the ferrous to ferric iron thus giving basaltic hornblendes.

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[1] Rosenbusch, H.: *Mikroskopische Physiographie,* II Aufl., Bd. 1, 463, 1885.

[2] Schneider, C.: Sur Kenntniss basaltischer Hornblenden. *Zeit. Kryst.,* 18, 580, 1891.

Table I

Locality	FeO	Extinction
Laacher See	7.03%	8½°
Altenbusch	6.27	6–8
Hartlingen	4.53	2–4
Wolkenburg	3.19	1–3
Bohmen	2.89	1
Ortenberg	0.57	0

During the same year Belowski[3] in a short article stated that he believed the change was due to oxidation. During the following year Belowski's[4] Inaugural-Dissertation was published; in this he elaborated his stand. He heated hornblende, actinolite and tremolite in a current of air and obtained in all, except the tremolite, an increase in double refraction and absorption, a decrease in the extinction angle ($Z \wedge c$) and a change in pleochroism from greens to browns. Table II shows the iron content before heating and the extinction angle before and after heating. He stated that: "Through the action of heat, oxidation is permitted to go on, changing green hornblende in rocks to brown hornblende." He cited as proof of this, hornblende crystals in some of the Ecuadorian rocks that have centers of green hornblende and borders (Resorptionränder) of brown hornblende.

Table II

Mineral	Locality	FeO	Fe_2O_3	Extinction Before	Extinction After
Hornblende	Arendal	6.97%	14.48%	18½°	0°
Actinolite	Zillerthal	6.25		14°	2°
Tremolite	Campo Longo	0.50		No change	

Weinschenk[5] in 1912 suggested that basaltic hornblende is due to the presence of ferric oxide and titanium oxide. He also noted the change in optical properties on heating.

[3] Belowski, M.: *Neues Jahrbuch für Mineralogie*, Bd. I, 219, 1891.

[4] Belowski, M.: Die Gesteine der Ecuatorianischen West-Cordillere von Tulcan bis zu den Escaleras-Bergen. *Inaugural-Dissertation.* Berlin, 1892.

[5] Weinschenk: *Petrographic Methods*, 291–292, 1912.

Winchell[6] in 1924 suggested that possibly the peculiar optical properties of "basaltic hornblende" are due to the presence of Ti_2O_3.

Graham[7] in 1926 heated common hornblende in carbon dioxide and obtained the usual changes in optical properties that are found on heating in air. He stated that, "These experiments strongly suggest that the water is the controlling constituent." In a footnote, however, he made the following statement: "It is possible there may have been oxidation by water driven from the hornblende during heating, but this is a reaction of the original parts of the mineral and not an oxidation from atmospheric oxidation."

Kôzu, Yoshiki and Kani[8] in 1927 heated hornblendes, common and basaltic, in nitrogen to prevent oxidation and found that the common hornblende changed to brown hornblende at about 750°C. They measured the expansion of the common hornblende in the direction of the *c*-axis during heating and found that at 750° contraction started in and continued to 790° at which point expansion again took place. The basaltic hornblendes gave a smooth curve of expansion over the same range of temperature. They stated that, "With regard to the fundamental cause producing the differences between these two varieties of hornblende, we can not say decidedly at present, but we are inclined to think they are due to the quantitative and structural changes in the main components, and are not only to be referred to the relative amounts of special constituents, such as the oxides of iron and titanium or the water in the crystal." They also showed that there is a break in the curve of loss of weight on heating for common hornblende between 700° and 800°C., at which point the loss of weight accelerates. Basaltic hornblende did not show this change. Table III gives the optical properties of unheated and heated hornblendes as obtained by them, and shows the increase of indices and birefringence, and the decrease of the extinction angle that takes place upon heating common hornblende and the lack of change obtained upon heating basaltic hornblende.

[6] Winchell, A. N.: *Am. Jour. Sci.*, 5th Ser. Vol. **7**, 287, 1924.

[7] Graham, W. A. P.: *Am. Mineral.*, Vol. **11**, No. 5, 118, 1926.

[8] Kôzu, S., Yoshiki, B., and Kani, K.: *Science Reports of the Tôhoku Imperial University*, Ser. 3, Vol. **III**, No. 2, 143, 1927.

TABLE III[9]

Unheated	1	2	3	4	5	6	7
N_p'	1.651	1.659	1.664	1.668	1.672	1.689	1.701
N_g'	1.660	1.675	1.673	1.682	1.684	1.719	1.731
$c\wedge Z'$	24°	13°	15°	18°	13°	0°	0°
Heated							
N_p'	1.681	1.688	1.690	1.714	1.695	1.689	1.701
N_g'	1.698	1.714	1.723	1.740	1.727	1.719	1.731
$c\wedge Z'$	0°	0°	0°	0°	0°	0°	0°

1. Green hornblende—Iratsuyama, Prov. Iyo.
2. Soretite—Otsurumizu, Prov. Bungo.
3. Common hornblende—Ishigami-mura, Prov. Iwaki.
4. Common hornblende—Kitayamagata-mura, Prov. Rikuchû.
5. Common hornblende—Kamimatama-mura, Prov. Bungo.
6. Basaltic hornblende—Ikebukuro, Sakai-mura, Prov. Shinano.
7. Basaltic hornblende—Shichiseizan, Formosa.

Reade[10] in 1928 heated common hornblende in hydrogen and found only a slight change in optical properties. He heated another sample in air and obtained the usual increase in birefringence and indices of refraction, decrease in the extinction angle ($Z\wedge c$) and change in color and pleochroism. This sample when reheated in hydrogen changed back to common hornblende.

In the fall of 1928 at the time the present work was started the most likely views published were three different solutions of the problem by Belowski, Graham and Kôzu and associates. Belowski attributed the change in optical properties to oxidation of ferrous to ferric iron, Graham thought dehydration to be the chief factor in the change and Kôzu and associates, although not making a direct statement, imply that the volume change and change of optical properties are due to inversion. With these views extant it was deemed advisable to introduce enough incontrovertible evidence to definitely prove which view or possibly combination of views is correct.

Since 1928 Kôzu and Yoshiki[11] have published another article which tends to uphold the oxidation theory and Kunitz[12] has published an article containing material that definitely proves oxidation. The present work is much more complete than either of the above and substantiates the conclusion by Kunitz, and furthermore treats of the manner in which the change takes place.

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[9] N_p' and N_g' are the minimum and maximum indices on a cleavage plate (110), and $c\wedge Z'$ is the extinction angle on the (110) face.

[10] Reade, H. O.: *B. A. Thesis*, University of Wisconsin, **1928.**

[11] Kôzu, S., and Yoshiki, B.: *Science Reports of the Tôhoku Imperial University*, 3rd Ser., Vol. **III,** No. 3, 177, 1929.

Kôzu and Yoshiki show, in their latest publication, that the volcano Sambé is composed of two similar types of rocks, the only difference being in the hornblendes and biotites. In one type the hornblende is common green and the biotite is meroxene, in the other the hornblende is basaltic and the biotite anomite. They believed the latter to have been formed by reheating of the rock to over 750°C. Table IV gives the ferrous iron content, the loss on ignition and the optical properties of these minerals. It is apparent that some of the ferrous iron has been oxidized and that volatile constituents have been lost in the change to basaltic hornblende and anomite-biotite. They stated that the common hornblende and biotite must have been formed in a less oxidizing medium and under a higher pressure.

Table IV

	Hornblende		Biotite	
	Basaltic	Common	Anomite	Meroxene
FeO	7.69%	10.97%	5.96%	10.32%
Loss	0.08%	0.23%	1.53%	2.76%
N_p'	1.708	N_p 1.661		
N_g'	1.746	1.675	N_g 1.706	N_g 1.643

Table V gives the results obtained by Kunitz, in his last paper, of analyses and optical properties of hornblendes before and after

Table V

	Before Heating				After Heating				Total Fe as FeO
	Fe_2O_3	$\frac{Fe_2O_3}{FeO}$	N_p	N_g	Fe_2O_3	$\frac{Fe_2O_3}{FeO}$	N_p	N_g	
N. Hampshire	2.83	0.196	1.638	1.659	10.20	1.31	1.655	1.676	16.96
Arendal	4.58	0.351	1.658	1.677	4.26	3.24	1.676	1.697	17.20

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[12] Kunitz, W.: Die Isomorphieverhaltnisse in der Hornblendegruppe. *Neues Jahrbuch für Mineralogie*, **LX** Beilage Band, Abt. A, Zweites Heft, 1930.

heating. He stated that it is quite evident that oxidation accounts for the changes shown in Table V.

PROCEDURE

In order to settle definitely the process involved in the change from green hornblende to brown hornblende a series of fourteen hornblende samples including edenite and pargasite were studied optically before and after heating to ascertain the amount of change involved. Formerly only the green or iron-rich hornblendes were studied. The study was extended to the tremolite-actinolite series of which six samples were studied optically before and after heating.

Other workers obtained a change upon heating in steam, carbon dioxide and nitrogen so it is unnecessary to repeat heatings with any of these agents as mediums. It was deemed advisable to repeat the experiment using hydrogen, so a sample that had already been heated in air was reheated at a temperature of about 850°C., in a stream of unwashed hydrogen, generated by the addition of hydrochloric acid to zinc, and the optical properties again determined. With a temperature of 850°C., it was necessary to paraffin all joints to make them air tight to avoid an explosion, and the exhaust hydrogen was passed through water which served as a check valve against the entrace of air.

To complete the study two chemical analyses were obtained of materials differing considerably in optical properties, but yet capable of being classified as common or green hornblende. Partial analyses were obtained of these samples after heating; namely the tenor of ferrous and ferric iron, water and fluorine. Two other analyses available, one of edenite and the other of tremolite, are helpful in interpretation of results, but since practically no change was found on heating they were not analyzed afterwards.

For heating the samples a furnace made from a glazed porcelain tube an inch in diameter wrapped with nichrome wire and insulated with asbestos was used. Temperatures were obtained on a Hoskins type H.A. "Thermoelectric" pyrometer. All of the experiments were conducted at a temperature of about 850°C., over a period of three hours in order to be sure that the change proceeded to completion.

The optical work was done on Emmons'[13] double variation modified universal stage in which is incorporated a Bausch & Lomb monochromator and Abbé refractometer, a Leitz universal stage modified by Emmons and a Leitz research model petrographic microscope. This apparatus embraces temperature and wavelength control. The temperature is regulated by a flow of water in series, first through the Abbé refractometer then through the cell on the universal stage, and is checked by two thermometers one on the refractometer and the other in the water line past the cell. With a strong flow of water the maximum difference between the thermometers is 2° at a temperature of 70°C. At lower temperatures the difference is inappreciable and usually double variation liquids are available to cover the range of index at these lower temperatures. At least five minutes are allowed after each temperature change before an index is read to allow the apparatus sufficient time to come to a constant temperature. The wavelength control is exercised through the monochromator and the width of the band of light used was for F, 150Å, for D, 320Å and for C, 460Å. The wave length used from this band is essentially a mean value. For determining indices several checks falling within a range of 40Å are obtained for the wave length at which the liquid is of the same index as the mineral.

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[13] Emmons, R. C.: *Am. Mineral.*, Vol. **13**, 504, 1928· *Am. Mineral*, Vol. **14**, 414, 1929; and *Am. Mineral.*, Vol. **14**, 441, 1929.

A mineral mount for the universal stage consists of two or three grains between a pair of cover glasses with a double variation liquid of the proper index as an immersion medium, and as a contact liquid between the cell and the lower cover glass, and between the upper cover glass and the upper hemisphere. To avoid dilution of the index liquids the refractometer and cell are cleaned thoroughly with acetone before and after each determination. The best appearing grain is chosen and worked to the center of the field where it is fixed by tightening the screws which hold the upper hemisphere in position, care being taken not to exert enough pressure to fracture the grain. The usual procedure as outlined by Emmons[14] is followed for orienting a grain on the universal stage. With hornblende at least 95 times out of a 100 the optic plane becomes vertical, enabling one to measure the optic angle and the indices N_g and N_m. N_p can usually be approached by rotating from either N_g or N_m, or, as in this work, from both, thus giving a check on the accuracy of the results. With rotation and optic angle readings it is necessary to correct the amount of rotation when there is a difference in index of the mineral and the hemispheres. This correction was obtained by using Plates I and IV in Emmons' article. For obtaining N_p from the rotation reading it is necessary to use Plate II of the same article. This orientation gives parallel extinction and to obtain the extinction angle of the clinopinacoid section ($Z \wedge c$), it is necessary to rotate toward N_p recording the amount of rotation and the extinction angle observed; from these data $Z \wedge c$ can be calculated by using the equation $(1/\mathrm{Sin}\,\alpha)\beta = Z \wedge c$, where α is the angle of rotation and β is the extinction angle at this rotation.

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[14] Emmons, R. C.: *Am. Mineral.*, Vol. **14**, 441, 1929.

The data recorded include wave-length, index, ray being measured, and temperature of both thermometers as well as the amount and direction of rotation in case rotation is necessary. Corrections must be applied to indices obtained at wave-lengths other than sodium light from a graph supplied with the Abbé refractometer. The optic angle can be calculated by using the indices from either the equation, $\mathrm{Sin}^2 V = N_m - N_p / N_g - N_p$, or the graphical solution of this equation.[15] A sample of each mineral before and after heating was mounted in balsam and several determinations of the optic angle and extinction angle ($Z \wedge c$) were made on each sample.

ACCURACY

Emmons states the accuracy expected using this set up in the publication cited above. In this study the probable error is stated for each determination, based on the number of determinations, the closeness of the checks, the clearness of the Becke line, the checks obtained on the monochromator, and the color of the mineral, which, when strong, partially masks the Becke line. The accuracy of the indices for the D or sodium line is about twice that for the indices of the F and C lines. The statement of error for the calculated optic angle is based on the statement of error for the indices and for the observed optic angle, it is estimated that the error can be ±2° for sodium light and about ±3° for F and C. Fig. I shows the accuracy to be expected, with a statement of error for the indices of ±.0002 and a birefringence of .0200. It will be noted that with the lowering of the optic angle the possible error increases rapidly. In comparing the optic angle obtained by observation and calculation it will be seen that the statement of error for the indices must in most cases be too large. The samples from Frankfort, Pa., and Renfrew, Ont., have an index for N_g which is above the double variation liquids used, so N_g was calculated from N_m, N_p and the observed optic angle.

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[15] Emmons, R. C.: *op. cit.*, Plate III.

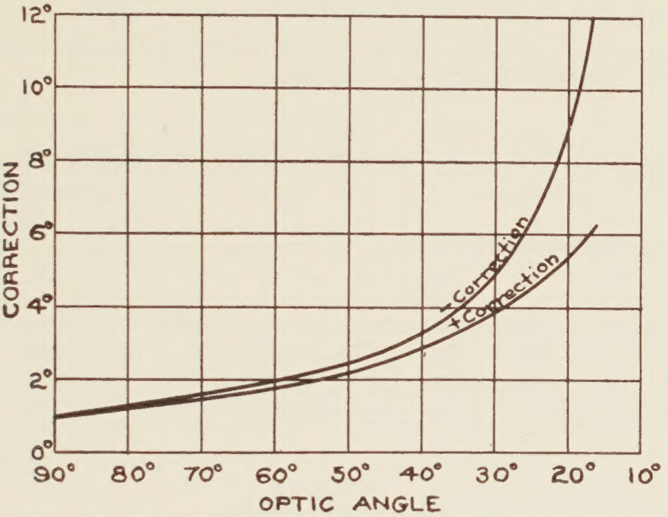

FIG. 1. Correction to be applied to the calculated optic angle, based on an assumed error of ±.0002 for the indices and an assumed birefringence of .0200.

In Table VI a comparison of the accuracy of this method with other methods is given using the mineral from Argenteuil Co., Quebec. Ford[16] used oriented plates and the total refractometer, and Kreutz[17] used mineral prisms and a crystal goniometer. These checks are rather close considering that the samples from which the optical properties were obtained may not be from the same out-

TABLE VI

	Ford	Kreutz	Barnes	Differences		
	A	B	C	A&B	A&C	B&C
N_g	1.6328	1.6332	1.6331	+.0004	+.0003	−.0001
N_m	1.6180	1.6180	1.6186	0	+.0006	+.0006
N_p	1.6128	1.6142	1.6143	+.0014	+.0015	+.0001
N_g-N_p	0.0200	0.0190	0.0188	−.0010	−.0012	−.0002
$2V$	56°8′	51°55′	57°	−4°	+1°	+5°
$Z\wedge c$	29°44′	27°34′	27°	−2°	$-2\frac{1}{2}°$	$-\frac{1}{2}°$

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[16] Ford, W. E.: *Am. Jour. Sci.*, **37**, 179, 1914.

[17] Kreutz, S.: *Sitz. Akad. Wiss. Wien.*, **117**, I, 875, 1908.

crop and that some hornblendes vary considerably in the same specimen. The check between the work of Kreutz and the present is the closer and speaks well for the accuracy of both methods. Kreutz also states the indices for several wave lengths, which are compared in Table VII with those obtained in the present work. Again excellent checks are obtained.

Table VII

Å	Kreutz A			Barnes B			Differences A&B		
	N_p	N_m	N_g	N_p	N_m	N_g	N_p	N_m	N_g
6710	1.6113	1.6149	1.6302	1.6113	1.6155	1.6295	0	.0006	.0007
5890	1.6142	1.6180	1.6332	1.6143	1.6186	1.6331	.0001	.0006	.0001
5350	1.6175	1.6211	1.6165	1.6175	1.6217	1.6363	0	.0006	.0002
4640		1.6270			1.6270			0	

Results

The results obtained in the present work show that the change of properties of the unheated hornblendes are in large part in direct proportion to the change in content of iron and that upon heating the properties are not changed at the iron-poor end of the series and are changed markedly at the iron-rich end of the series. The water content apparently has little effect on the optical properties as shown by lack of change in the low-iron hornblende when water is driven off. Inversion is found untenable as an explanation of the changes because no change takes place upon heating in hydrogen and because a chemical change takes place when heated in any other medium. Oxidation is proven to be the outstanding process causing the change in optical properties, as shown by optical studies before and after heating in both air and hydrogen, by the relation of weight-percent loss to the percentage of water from analysis, and by analyses of hornblende before and after heating.

The results of the present optical study are stated in Table VIII and are plotted on Plates I to IV. In plate I the properties of the hornblende series are plotted using the average index of the unheated samples as a straight line variation. This plate shows more clearly than the tables the lack of change in the iron-poor end of

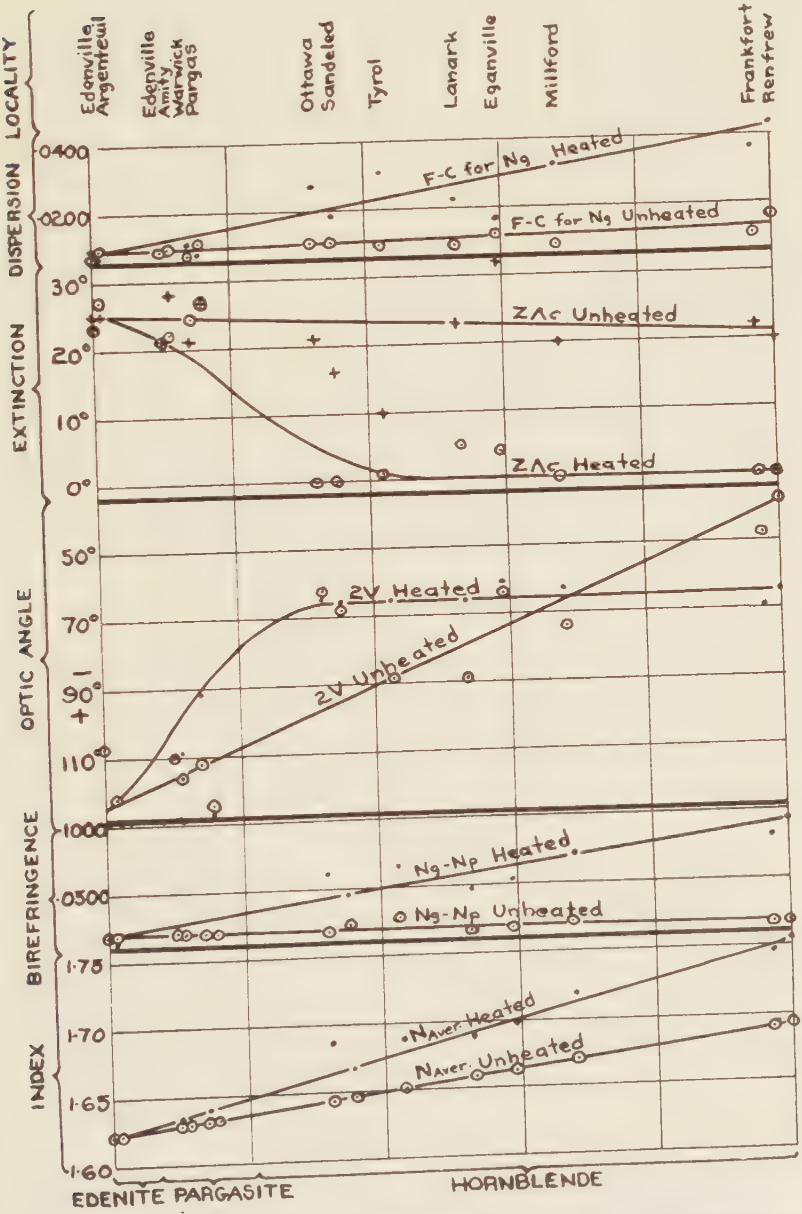

PLATE 1. Optical properties of the hornblende series plotted on the basis of the average index of the unheated hornblende as a straight line variation.

the hornblende series and the large change in the iron-rich portion of the series. This diagram shows, as is already known, that the hornblende series is of too complex a nature to be represented on a two dimension diagram. Generalizations that may be drawn

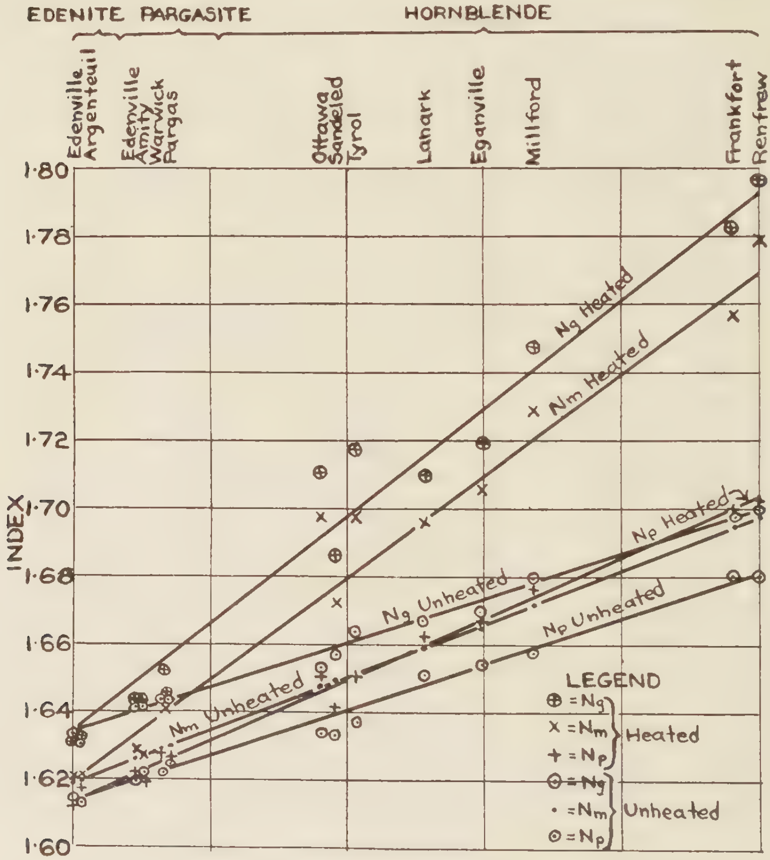

Plate II. Indices of the hornblende series plotted on the basis of N_m of the unheated hornblendes as a straight line variation.

from Plate I are that the hornblendes with appreciable iron, on heating, increase markedly in average index, birefringence and dispersion, decrease in extinction angle ($Z \wedge c$) to near zero degrees and have a change of optic angle to near 65°. The optic angle in the hornblende series measured about X ranges from 38° at the high-iron end of the series to 125° at the pargasite-edenite end of the series. The optical properties of edenite and pargasite are almost the same, the only marked difference being in color. It would be well to designate all the positive hornblendes under one name, preferably pargasite since it has priority in usage.

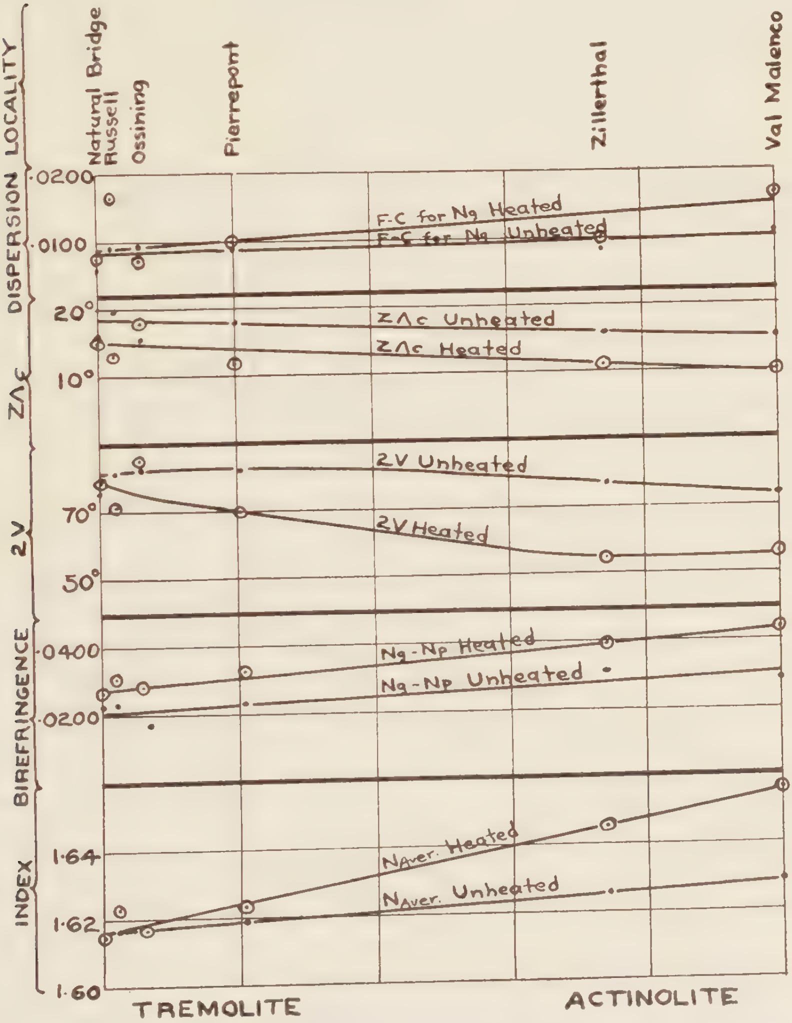

PLATE III. Optical properties of the tremolite-actinolite series plotted on the basis of the average index of the unheated samples as a straight line variation.

In Plate II the indices are plotted on the basis of N_m of the unheated samples as a straight line variation and the diagram shows the increase of indices with the increase in iron and the marked increase of indices upon heating at the high-iron end of the series. Plates III and IV are of the tremolite-actinolite series and are plotted on the same basis and show about the same facts as Plates I and II, respectively.

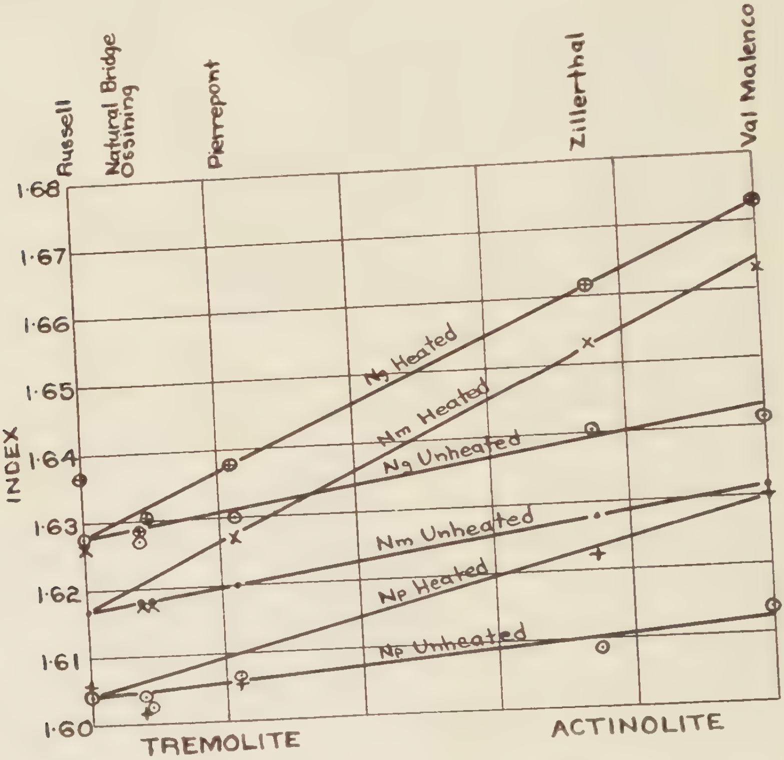

PLATE IV. Indices of the tremolite-actinolite series plotted on the basis of N_m of the unheated samples as a straight line variation.

The optical properties of the sample from Lanark Co., Ontario, when reheated in hydrogen returned practically to the same value as in the original sample before heating, indicating that ferric iron has been reduced to ferrous iron.

TABLE VIII

Hornblende—Var. Edenite, Grenville Township, Argenteuil Co., Quebec.[18]
Unheated
Error[19] ± .0002

	N_g	N_m	N_p	N_g-N_p	2V Calc.	2V Obs.	$Z\wedge c$	Pleochroism
F	1.6394	1.6252	1.6209	.0185	58° ±4°	58°±3°		None
D	1.6331	1.6186	1.6143	.0188	57° ±2°	58°±2°	27°±1°	
C	1.6300	1.6160	1.6117	.0183	58° ±4°	58°±3°		

Heated
Error ± .0002

F	1.6369	1.6255	1.6221	.0148	57½°±6°	58°±3°		None
D	1.6317	1.6204	1.6170	.0147	57½°±3°	58°±2°	25°±1°	
C	1.6294	1.6178	1.6144	.0150	57° ±6°	58°±3°		

Hornblende—Var. Edenite, Edenville, N. Y.
Unheated
Error ± .0005

F	1.6361	1.6245	1.6181	.0180	73° ±8°	74°±3°		None
D	1.6307	1.6190	1.6125	.0182	73½°±4°	74°±2°	23°±1°	
C	1.6286	1.6166	1.6098	.0188	74½°±8°	74°±3°		

Heated
Error ± .0005

F	1.6375	1.6263	1.6198	.0177	74½°±8°	74°±3°		None
D	1.6311	1.6204	1.6138	.0173	76° ±4°	74°±2°	25°±2°	
C	1.6288	1.6178	1.6112	.0176	75½°±8°	74°±3°		

Hornblende—Var., Pargasite, Edenville, N. Y.
Unheated
Error ± .0003

F	1.6464	1.6313	1.6245	.0219	67½°±6°	70°±3°		None
D	1.6410	1.6256	1.6188	.0222	67½°±3°	70°±2°	21°±1°	
C	1.6382	1.6231	1.6162	.0220	68½°±6°	70°±3°		

Heated
Error ± .0005

F	1.6492	1.6348	1.6279	.0213	69½°±6°	71°±3°		None
D	1.6430	1.6291	1.6221	.0209	71° ±3°	71°±2°	21°±1°	
C	1.6406	1.6264	1.6197	.0209	69° ±6°	71°±3°		

[18] This sample was furnished by the Canadian Geological Survey, and is one of the most studied amphiboles, having been analyzed by three different people, Harrington, Jōhnston and Stanley, and studied optically by Ford and Kreutz.

[19] This error refers only to the indices for the *D* line. For a fuller discussion of accuracy see text.

Hornblende—Var. Pargasite, Amity, New York
Unheated
Error ± .0005

	N_g	N_m	N_p	N_g-N_p	2V Calc.	2V Obs.	$Z \wedge c$	Pleochroism
F	1.6484	1.6338	1.6283	.0201	63° ±8°	64°±3°		None
D	1.6416	1.6265	1.6206	.0210	64° ±4°	64°±2°	22°±1°	
C	1.6383	1.6233	1.6175	.0208	66° ±8°	64°±3°		
Heated								
Error ± .0005								
F	1.6476	1.6332	1.6262	.0214	68° ±8°	70°±3°		None
D	1.6413	1.6265	1.6190	.0223	71° ±4°	70°±2°	28°±2°	
C	1.6378	1.6227	1.6148	.0230	71½°±8°	70°±3°		
Hornblende—Var. Pargasite, Warwick, N. Y.								
Unheated								
Error ± .0002								
F	1.6480	1.6325	1.6259	.0221	66° ±4°	66°±3°		X = Colorless
D	1.6429	1.6284	1.6218	.0211	68° ±2°	66°±2°	24°±1°	Y = Very light green
C	1.6411	1.6265	1.6203	.0208	66° ±4°	66°±3°		Z = Very light brownish green
Heated								
Error ± .0005								
F	1.6599	1.6472	1.6354	.0245	88° ±4°	86°±3°		X = Very light green
D	1.6526	1.6402	1.6287	.0239	88° ±2°	86°±2°	21°±1°	Y = Light brownish green
C	1.6492	1.6370	1.6256	.0236	88° ±4°	86°±3°		Z = Light brown
Hornblende—Var. Pargasite, Pargas, Finland								
Unheated								
Error ± .0005								
F	1.6511	1.6360	1.6318	.0193	56° ±8°	56°±3°		None
D	1.6437	1.6286	1.6244	.0193	55½°±4°	56°±2°	27°±1°	
C	1.6401	1.6250	1.6208	.0193	56° ±8°	56°±3°		
Heated								
Error ± .0003								
F	1.6510	1.6351	1.6314	.0196	51½°±6°	53°±3°		None
D	1.6451	1.6297	1.6260	.0191	52½°±3°	53°±2°	27°±1°	
C	1.6427	1.6265	1.6228	.0199	51° ±6°	53°±3°		
Hornblende, Ottawa, Canada								
Unheated								
Error ± .0002								
F	1.6600	1.6551	1.6423	.0177	63° ±4°	62°±3°		X = Light bluish green
D	1.6522	1.6472	1.6341	.0181	63° ±2°	62°±2°	21°±1°	Y = Deep green
C	1.6490	1.6440	1.6311	.0179	64° ±4°	62°±3°		Z = Deep bluish green
Heated								
Error ± .0005								
F	1.7288	1.7095	1.6596	.0692	64° ±4°	64°±3°		Y = Yellowish brown
D	1.7111	1.6978	1.6503	.0608	55½°±2°	56°±2°	0°±1°	Y = Amber brown
C	1.7016	1.6917	1.6478	.0538	51° ±4°	52°±3°		Z = Deep dark brown

Hornblende, Sandeled, near Risor, Norway
Unheated
Error ± .0005

	N_g	N_m	N_p	N_g-N_p	2V Calc.	2V Obs.	$Z\wedge c$	Pleochroism
F	1.6642	1.6572	1.6421	.0221	69° ±8°	72°±3°		X=Light green
D	1.6571	1.6490	1.6331	.0240	71° ±4°	72°±2°	16°±1°	Y=Yellowish green
C	1.6536	1.6457	1.6297	.0239	70° ±8°	72°+3°		Z=Dark yellowish green

Heated
Error ± .0004

F	1.6980	1.6838	1.6520	.0460	66° ±4°	66°±3°		X=Light greenish brown
D	1.6862	1.6724	1.6406	.0456	67° ±2°	66°±2°	0°±1°	Y=Greenish brown
C	1.6798	1.6678	1.6367	.0431	64° ±4°	66°±3°		Z=Deep brown

Hornblende, Tyrol
Unheated
Error ± .0005

F	1.6713	1.6585	1.6445	.0268	87° ±4°	86°±3°		X=Very light green
D	1.6640	1.6510	1.6370	.0271	88° ±2°	86°±2°	10°±1°	Y=Light grayish green
C	1.6618	1.6494	1.6347	.0371	85½°±4°	86°±3°		Z=Grayish green

Heated
Error ± .0010

F	1.7411	1.7152	1.6623	.0788	70° ±4°	70°±3°		X=Light amber
D	1.7175	1.6980	1.6507	.0668	65½°±2°	65°±2°	1°±1°	Y=Amber brown
C	1.7093	1.6928	1.6473	.0620	62° ±4°	62°±3°		Z=Deep brown

Hornblende, Lanark Co., Ontario[20]
Unheated
Error ± .0002

F	1.6732	1.6668	1.6608	.0124	88° ±4°	88°±3°		X=Very light green
D	1.6665	1.6589	1.6511	.0154	89½°±2°	88°±2°	23°±2°	Y=Brownish green
C	1.6641	1.6557	1.6473	.0168	90° ±4°	88°±3°		Z=Green

Heated
Error ± .0005

F	1.7243	1.7083	1.6726	.0517	68° ±4°	76°±3°		X=Light greenish brown
D	1.7100	1.6961	1.6626	.0474	66° ±2°	66°±3°	5°±2°	Y=Amber brown
C	1.7014	1.6890	1.6581	.0433	65° ±4°	64°±3°		Z=Deep brown

Reheated in hydrogen
Error ± .0004

F	1.6737	1.6659	1.6581	.0156	90° ±4°	88° ±3°		X=Very light green
D	1.6670	1.6583	1.6493	.0177	89° ±2°	88°±2°	24°±2°	Y=Brownish green
C	1.6650	1.6562	1.6464	.0186	87° ±4°	88°±3°		Z=Green

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[20] Analysis by R. B. Ellestad, University of Minnesota.

	N_g	N_m	N_p	N_g-N_p	2V Calc.	2V Obs.	$Z\wedge c$	Pleochroism
Hornblende, Eganville, Ontario Unheated Error ± .0003								
F	1.6786	1.6735	1.6614	.0172	66° ±4°	63°±3°		X=Light green
D	1.6702	1.6656	1.6539	.0163	64° ±2°	63°±2°	32°±1°	Y=Deep green
C	1.6660	1.6616	1.6499	.0161	63° ±4°	63°±3°		Z=Deep blue green
Heated Error ± .0010								
F	1.7311	1.7168	1.6741	.0570	60° ±8°	61°±3°		X=Greenish brown
D	1.7193	1.7060	1.6666	.0527	61° ±4°	61°±2°	4°±2°	Y=Dark greenish brown
C	1.7148	1.7017	1.6635	.0513	62° ±8°	61°±3°		Z=Opaque brown
Hornblende, Millford, Massachusetts Unheated Error ± .0005								
F	1.6856	1.6788	1.6663	.0193	73° ±6°	72°±3°		X=Yellowish green
D	1.6792	1.6715	1.6578	.0214	74° ±3°	72°±2°	20°±1°	Y=Dark yellow green
C	1.6766	1.6686	1.6549	.0217	74½°±6°	72°±3°		Z=Dark bluish green
Heated Error ± .0008								
F	1.7729	1.7450	1.6884	.0845	70° ±6°	72°±3°		X=Yellowish green
D	1.7477	1.7288	1.6759	.0718	62° ±3°	65°±2°	0°±1°	Y=Dark amber brown
C	1.7399	1.7206	1.6719	.0680	64½°±6°	63°±3°		Z=Deep brown
Hornblende, Frankfort, Pennsylvania Unheated Error ± .0004								
F	1.7073	1.7043	1.6900	.0173	49° ±12°	45°±3°		X=Light yellow green
D	1.6980	1.6950	1.6801	.0179	48° ±6°	45°±2°	22°±1°	Y=Yellowish green
C	1.6960	1.6930	1.6765	.0195	47° ±12°	45°±3°		Z=Bluish green
Heated Error ± .0012								
F	1.8068	1.7759	1.7137	.0931	———	70°±3°		X=Yellow green
D	1.7825	1.7564	1.7003	.0822	———	69°±2°	0°±1°	Y=Opaque yellow green
C	1.7706	1.7483	1.6962	.0744	———	66½°±3°		Z=Opaque
Hornblende, Renfrew Co., Ontario[21] Unheated Error ± .0005								
F	1.7110	1.7090	1.6908	.0202	37° ±14°	35°±3°		X=Light green
D	1.7000	1.6980	1.6804	.0196	38° ±7°	38°±4°	20°±1°	Y=Dark green
C	1.6948	1.6930	1.6758	.0190	36° ±14°	40°±3°		Z=Very dark green
Heated Error ± .0012								
F	1.8275	1.7857	1.7145	.1130	———	75°±3°		X=Light brown
D	1.7960	1.7690	1.7020	.0940	———	65°±2°	0°±1°	Y=Dark brown
C	1.7838	1.7608	1.6973	.0865	———	62°±3°		Z=Very dark brown

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[21] Analysis by L. C. Hurd, University of Wisconsin.

Tremolite, Russell, New York
Unheated
Error ± .0002

	N_g	N_m	N_p	N_g-N_p	2V Calc.	2V Obs.	$Z\wedge c$	Pleochroism
F	1.6342	1.6230	1.6096	.0246	85° ±4°	81°±3°		None
D	1.6278	1.6178	1.6042	.0236	81½°±2°	81°±2°	20°±1°	
C	1.6252	1.6154	1.6016	.0236	80½°±4°	81°±3°		
Heated Error ± .0004								
F	1.6488	1.6350	1.6105	.0383	74° ±4°	72°±3°		X=Colorless
D	1.6367	1.6262	1.6058	.0309	71½°±2°	72°±2°	13°±1°	Y=Very light green
C	1.6323	1.6228	1.6047	.0276	72° ±4°	72°±3°		Z=Very light brown
Tremolite, Natural Bridge, New York Unheated Error ± .0004								
F	1.6303	1.6218	1.6076	.0227	75½°±4°	77°±3°		None
D	1.6267	1.6181	1.6041	.0226	76° ±2°	77°±2°	16°±1°	
C	1.6247	1.6161	1.6020	.0227	76° ±4°	77°±3°		
Heated Error ± .0005								
F	1.6335	1.6224	1.6061	.0274	79° ±6°	83°±3°		None
D	1.6284	1.6175	1.6014	.0270	79° ±3°	83°±2°	15°±1°	
C	1.6258	1.6147	1.5991	.0267	80° ±6°	83°±3°		
Tremolite, Ossining, New York[22] Unheated Error ± .0002								
F	1.6369	1.6245	1.6086	.0283	83° ±4°	82°±3°		None
D	1.6307	1.6183	1.6024	.0283	83° ±2°	82°±2°	15½±1°	
C	1.6278	1.6155	1.5996	.0282	83° ±4°	82°±3°		
Heated Error ± .0004								
F	1.6355	1.6228	1.6080	.0275	85½°±4°	82°±3°		None
D	1.6308	1.6178	1.6026	.0282	85½°±2°	82°±2°	18°±1°	
C	1.6282	1.6152	1.6002	.0280	86° ±4°	82°±3°		
Actinolite, Pierrepont, New York Unheated Error ± .0004								
F	1.6367	1.6271	1.6131	.0236	79° ±4°	82°±3°		None
D	1.6301	1.6201	1.6067	.0234	82° ±2°	82°±2°	18°±1°	
C	1.6276	1.6169	1.6037	.0239	84° ±4°	82°±3°		
Heated Error ± .0004								
F	1.6443	1.6328	1.6106	.0337	71½°±4°	70°±3°		X=Colorless
D	1.6377	1.6270	1.6053	.0324	70° ±2°	70°±2°	12°±1°	Y=Very light green
C	1.6343	1.6242	1.6032	.0311	69½°±4°	70°±3°		Z=Very light brown

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[22] Analysis by Allen and Clement: *Amer. Jour. Sci.*, 4th Ser., Vol. 26, 101, 1908. The material studied is a portion of the original sample that was analyzed.

	N_g	N_m	N_p	N_g-N_p	2V Calc.	2V Obs.	Z∧c	Pleochroism
Actinolite, Zillerthal, Tyrol Unheated Error ± .0005								
F	1.6463	1.6332	1.6142	.0321	79° ± 4°	78° ± 3°		X = Very light green
D	1.6403	1.6278	1.6085	.0318	77½° ± 2°	78° ± 2°	16° ± 1°	Y = Yellowish green
C	1.6380	1.6253	1.6060	.0320	78° ± 4°	78° ± 3°		Z = Green
Heated Error ± .0010								
F	1.6679	1.6594	1.6283	.0396	55° ± 10°	56° ± 3°		X = Light green
D	1.6617	1.6532	1.6220	.0397	55° ± 5°	56° ± 2°	11° ± 1°	Y = Greenish brown
C	1.6581	1.6496	1.6183	.0398	55° ± 10°	56° ± 3°		Z = Mottled brown
Actinolite, Val Malenco, Italy[23] Unheated Error ± .0004								
F	1.6490	1.6384	1.6214	.0276	76½° ± 4°	73° ± 3°		X = Light green
D	1.6413	1.6313	1.6133	.0280	73½° ± 2°	73° ± 2°	15° ± 1°	Y = Bluish green
C	1.6379	1.6280	1.6108	.0271	74½° ± 4°	73° ± 3°		Z = Green
Heated Error ± .0005								
F	1.6848	1.6743	1.6380	.0468	56½° ± 6°	57° ± 3°		X = Greenish brown
D	1.6728	1.6634	1.6301	.0427	56° ± 3°	56° ± 2°	10° ± 1°	Y = Deep brown
C	1.6680	1.6586	1.6278	.0402	58° ± 6°	55° ± 3°		Z = Dark brown

Kreutz[24] mentions that for common hornblende the birefringence in red is greater than for violet and that for basaltic hornblende the opposite is true. The results obtained in this study bear out, in general, the results obtained by Kreutz for common hornblende and entirely for brown hornblende. The heated hornblende also shows a marked rhombic dispersion as indicated by the difference of the optic angle for F and C calculated from the indices and observed directly.

In dehydration of amphiboles hydrogen is given off and not water (except water which is not a constituent part of the space lattice). This is substantiated by the difference between the weight percentage loss on heating and the water content by analysis. The percentage loss in weight of the Lanark County hornblende upon heating was 0.27% and the analysis for water gave 0.74%. The sample from Argenteuil Co., Quebec, shows a weight loss of 0.04% and the water content by analysis is 0.58%. Kôzu[25] and associates show a weight-percent loss for common hornblende of 0.13% and for soretite of 0.28% at a temperature of 800°C., which compares with the temperature used here, and at 1000° the weight-percent loss is 0.18% and 0.49%, respectively. The water analysis is not given for either of these samples, but it is reasonable to assume that as in other amphiboles the analyses would show about 1% or more of water. The reason it is thought that hydrogen is given off and not water given off and oxygen taken on is that the sample from Argenteuil Co., Quebec, which is very low in iron shows a weight percentage loss that is only a small fraction of the water contained, and since little iron is present there would be no reason for oxygen to enter the mineral. The oxygen which remains in the mineral must (if ferrous iron is available) oxidize the ferrous iron to ferric iron, and when no ferrous iron is present must be held in the mineral by its size and consequently its inability to move through the space lattice.

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[23] No. 11453 of the Milwaukee Museum.

[24] Kreutz, S.: *Sitz. Akad. Wiss. Wien.*, **117**, I, 875, 1908.

[25] Kôzu, S., Yoshiki, B., and Kani, K.: *Science Reports of the Tôhoku Imperial University*, Ser. 3, Vol. **III**, No. 2, 143, 1927.

To establish oxidation definitely we may turn to the analyses of the Renfrew and Lanark hornblendes, before and after heating, in Table IX. In both samples it is very apparent that a large share of the ferrous iron has been converted into ferric iron and that

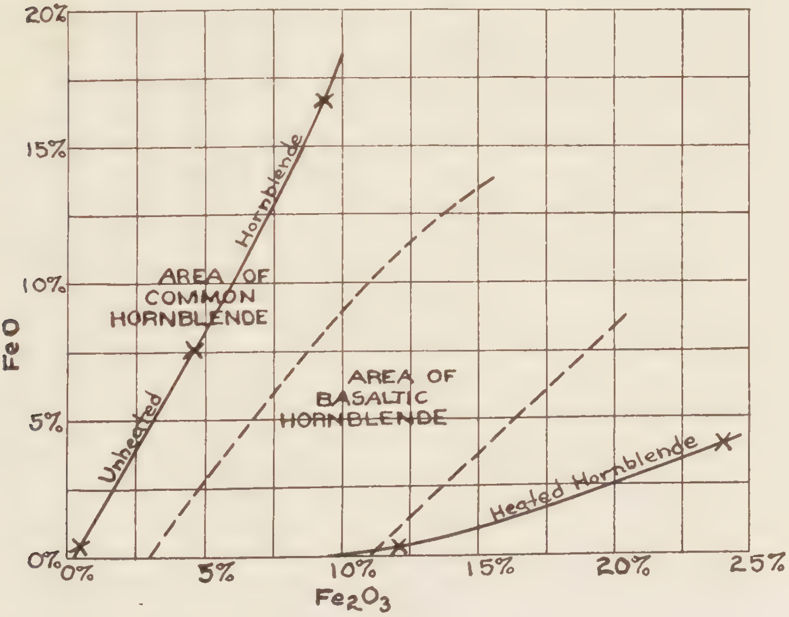

Fig. 2. Relations between ferrous and ferric iron in analyzed samples of common, basaltic, and heated hornblende.

water has been lost. Two other analyses of iron-poor amphiboles that show very little optical change on heating are included in the table. Analyses after heating were not made because the small optical change indicates practically no chemical change.

The total iron is stated for the unheated and heated phases of the Lanark and Renfrew hornblendes. The total iron for the Lanark sample checks within 0.04% and from all appearances the analysis is excellent. The total iron in the Renfrew sample is over twice that in the Lanark sample. The analyses before and after heating show a discrepancy of 0.28% for total iron and the accuracy given for the fluorine indicates that it is little better than an estimate, so this analysis should be used with discretion.

Table IX

	1	2	3	4	5	6
SiO_2	43.59		41.02		45.79	57.35
TiO_2	0.86		1.02		0.63	0.07
Al_2O_3	11.17		9.69		12.18	1.21
Fe_2O_3	4.60	12.42	9.23	23.40	0.50	0.11
FeO	7.48	0.39	16.51	4.12	0.39	0.23
MnO	0.29		tr.		0.29	0.01
MgO	14.59		7.20		20.85	23.87
CaO	11.60		10.65		12.98	14.02
K_2O	1.95		1.33		1.76	0.19
Na_2O	2.49		2.72		2.54	0.42
H_2O	0.74	0.05	0.92	0.08	0.58	2.21
F_2	0.29	0.34	0.40±.20	0.30±.20	2.80	0.11
Total	99.65		100.68		101.29	99.80
$O=F_2$	.12		.18		1.17	.05
	99.53		100.50		100.12	99.75
Total Fe	9.03	8.99	19.29	19.57		

1. Unheated hornblende, Lanark Co., Ont. Analyzed by R. B. Ellestad, University of Minnesota.

2. Heated, otherwise the same as 1.

3. Unheated hornblende, Renfrew Co., Ont. Analyzed by L. C. Hurd, University of Wisconsin.

4. Heated, otherwise the same as 3.

5. Edenite, Argenteuil Co., Quebec. Average of analyses by Harrington, B. J.: *Am. Jour. Sci.*, **XV**, 392, 1903; Johnston, R. A. A.: *Geol. Sur. Canada*, Vol. **XIII**; and Stanley, F. C.: *Am. Jour. Sci.*, **XXIII**, 49, 1907.

6. Tremolite, Ossining, N.Y. Analysis by Allen and Clement, *Am. Jour. Sci.*, 4th Ser., Vol. **26**, 101, 1908.

The optical properties were plotted against the content of iron oxides and also against the ratio of combined iron oxides to magnesia. In both cases the resulting diagrams were almost exactly the same as obtained in Plate I in which the average index of the heated hornblendes were plotted as a straight line variation. In Fig. 2, ferrous iron is plotted on the ordinate and ferric iron on the abscissa. The areas of common hornblende and of basaltic hornblende are shown as obtained from many analyses. The analyses from Table IX are indicated by crosses, and it will be noticed that for the heated samples the crosses fall outside of the basaltic hornblende area. It is probable that most basaltic hornblendes are not fully oxidized. This view is supported by Schneider, previously quoted, who heated basaltic hornblendes and found in most of them an increase in pleochroism, absorption and double refraction, and a decrease in extinction angle ($Z \wedge c$).

The density of the heated hornblende is greater than that of the unheated hornblende. Using Clerici solution the density of the Lanark Co., sample was determined to be 3.175 in the unheated state and 3.215 afterwards, and for the Renfrew Co. sample the density was determined to be 3.258 for the unheated sample and 3.320 for the one that was heated. Graham[26] states that, "The diffraction-angles of the heated sample are slightly greater than in the unheated one, indicating that in the heated hornblendes the planes of atomic structure are a trifle closer together and the mineral is slightly denser." Kôzu and associates, previously quoted, found a contraction between the temperatures of 750° and 790° C., which is additional evidence that the heated hornblendes are denser. Kôzu attributed this change to inversion. Many substances do show this phenomenon at the inversion point, but with inversion there is only a rearrangement of the material present and no change in chemical composition by either addition or expulsion. It may be argued that the effects of the chemical changes taking place are subordinate as shown by the lack of change of the iron-poor amphiboles upon the loss of water, but at the same time there is no change to indicate inversion. Inversion should take place without regard to the atmosphere in which it is heated. As found in the present study the high-iron hornblendes when heated in hydrogen do not change. If inversion were the chief factor the change of mean index should be related to the change in density. This was tested with the aid of the formula of Gladstone & Dale:[27] $n-1/d=$constant, where n is the index and d is the density. The constant obtained for the unheated sample was used with the density of the heated sample to obtain the index. The Lanark Co. sample gives an increase of mean index of .0083 due to density increase, whereas, the measured increase of mean index is .0308. Following the same procedure for the Renfrew Co. sample .0132 is obtained for the increase in mean index due to density and .0625 is the mean index increase observed. The increase of index due to the increase of density is only about one-quarter of the increase actually found. The accuracy of this formula for solids is seriously questioned, so these results cannot be regarded as more than approximations.

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[26] Graham, W. A. P.: *Am. Mineral.*, Vol. **XI**, No. 5, 118, 1926.

Oxidation is by far the most important factor in the change from green to brown hornblende and in fact if it were not for oxidation there would be no increase in density and consequently no increase in index from this cause.

SUMMARY

The facts obtained in this study may be enumerated as follows:

1. Green hornblende, when heated in air, changes to brown hornblende, which has the same optical properties as basaltic hornblende.
2. The iron-poor hornblendes do not change on heating.
3. Upon heating tremolite behaves like the iron-poor hornblendes and actinolite like the iron-containing hornblendes.
4. The changes obtained in the iron-rich varieties upon heating are as follows: Increase in density, indices of refraction, birefringence, and dispersion; decrease in extinction angle; and change in optic angle to about 65°, and in pleochroism and color from greens to browns.
5. Brown hornblende when heated in hydrogen changes back to green hornblende.
6. The weight-percent loss on heating is only a fraction of the water obtained by analysis.
7. The birefringence of brown hornblende in violet is greater than for red and the opposite is true in general for common hornblende.

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[27] Gladstone and Dale: *Phil. Trans.*, **153**, 317, 1863.

8. The heated, iron-rich hornblendes show a marked rhombic dispersion.

9. The analyses show a marked conversion of ferrous to ferric iron on heating and a loss in water.

10. The optical properties change almost in proportion to the change in the total iron oxides, with ferric iron being the most influential upon the optical properties.

11. Dehydration has little effect upon the optical properties.

12. Heated hornblendes in general have a more complete change of ferrous to ferric iron than basaltic hornblendes.

The conclusions drawn from these facts are as follows:

1. Oxidation of ferrous to ferric iron causes the changes in optical properties observed upon heating common hornblende.

2. Dehydration is of no importance except that it allows oxidation to proceed.

3. Inversion is not present as proved by the lack of change when heated in hydrogen.

4. In dehydration, hydrogen and not water (except water that is not a constituent part of the space lattice) is given off, and the oxygen remains in the mineral, either oxidizing ferrous to ferric iron or, when ferrous iron is not present, remaining because of its size.

SUGGESTIONS AS TO STANDARDIZING THE NAMES OF THE CRYSTAL FORMS*

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The names for the crystal forms in common use in this country have been brought together from a variety of sources, and as a result they not only lack uniformity, but in some cases are unnecessarily complicated, ambiguous, or even incorrect. Some proposals directed toward the improvement of this situation are here put forward, in the hope that discussion may be started which will ultimately lead to the adoption of a set of standard terms as free as practicable from such objectionable features.

It is felt that the closed forms which occur in this system should be systematically assigned terms which state the *number* of faces present in each, with prefixes describing their arrangement when necessary. Terms which refer to the shapes of faces of the theoretical forms seem particularly objectionable, in view of the extreme rarity of crystals bounded by single forms (except of course (100) and (111)); thus to call a form a trapezohedron when its faces on natural crystals are actually trapeziums in only the most exceptional cases is incongruous and misleading. The selection of the form-names listed in the last column of the above tabulation has been based on these considerations.

In the holosymmetric class no new terms are required. The name for (*hhl*) is often spelled with an *s* between the *i* and *o*, but this seems unnecessary and is omitted in the interest of simplification.

The one form which is unique in the holoaxial class is frequently called a pentagonal-icositetrahedron, but this is both unduly long and misleading in that the faces almost never have pentagonal shape in nature; as its peculiar feature is a gyroidal arrangement, *gyricositetrahedron* is proposed as the simplest name adequately describing it.

For (*hk0*) in the alternating class there are two terms in common use, pentagonal-dodecahedron, which is erroneous in that the geometrical solid to which this name properly belongs can not

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* Presented at the annual meeting of the *Mineralogical Society of America*, Dec. 28, 1929.

CUBIC SYSTEM

	Class[1]	Representative	Symbol	Form-names	
				Undesirable	Proposed
O^h	Holosymmetric	fluorite	(100)	cube	hexahedron
			(111)		octahedron
			(110)	rhombic dodecahedron	dodecahedron
			(hk0)		tetrahexahedron
			(hhl)	trisoctahedron	trioctahedron
			(hll)	trapezohedron	icositetrahedron
			(hkl)		hexoctahedron
O	Holoaxial	cuprite	(hkl)	plagihedron	gyricositetrahedron
T^h	Alternating	pyrite	(hk0)	pyritohedron	dihexahedron
			(hkl)	diploid	didodecahedron
T^d	Alternating-polar	sphalerite	(111)		tetrahedron
			(hhl)	tetragonal-trisoctahedron	hemicositetrahedron
			(hll)	trigonal-tristetrahedron	tritetrahedron
			(hkl)		hextetrahedron
T	Digonal-polar	ullmannite	(hkl)	tetartohedron	gyrotritetrahedron

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[1] The class-names are those proposed by the writer, *Am. Min.*, **12**, 219, 1927, with modifications in some of the hexagonal classes to accord with space-group theory; the Schönfliess space-group symbols are entered at the left side opposite each name.

TETRAGONAL SYSTEM

	Class	Representative	Symbol	Form-names	
				Undesirable	Proposed
	Tetragonal subsystem				
D_4^h	Holosymmetric	octahedrite	(001)	base, basal pinacoid	pinacoid
			(100)	2nd order prism	normo-prism
			(110)	1st order prism	chordo-prism
			(hk0)	ditetragonal prism	duplo-prism
			(h0l)	2nd order dipyramid	normo-dipyramid
			(hhl)	1st order dipyramid	chordo-dipyramid
			(hkl)	ditetragonal dipyramid	duplo-dipyramid
C_4^v	Polar	silver fluoride	(001)	pedion, "pinacoid"	monohedron
			(h0l)	2nd order pyramid	normo-pyramid
			(hhl)	1st order pyramid	chordo-pyramid
			(hkl)	ditetragonal pyramid	duplo-pyramid
D_4	Holoaxial	nickel sulfate	(hkl)	trapezohedron	gyro-dipyramid
C_4^h	Monoaxial	scheelite	(hk0)	3rd order prism	clino-prism
			(hkl)	3rd order dipyramid	clino-dipyramid
C_4	Monoaxial-polar	wulfenite	(hkl)	3rd order pyramid	clino-pyramid
	Alternating subsystem				
V^d	Alternating	chalcopyrite	(hhl)	disphenoid, 1st order	chordo-disphenoid
			(hkl)	scalenohedron	duplo-disphenoid
S_4	Alternating-monoaxial	meliphanite	(h0l)	2nd order disphenoid	normo-disphenoid
			(hkl)	3rd order disphenoid	clino-disphenoid

occur on crystals, and pyritohedron, which is not descriptive of the form at all. The corresponding form in the holosymmetric class being well characterized by the name tetrahexahedron, in the present class the simple term *dihexahedron* seems to fulfil all requirements. Similarly, the complex expressions often used for the (*hkl*) form may be simplified to *didodecahedron*.

In the alternating-polar class the only wholly new name proposed is that for (*hhl*). For reasons already stated, the usual face-shape names for this form are considered undesirable, but a substitute which is reminiscent of the corresponding holosymmetric form is *hemicositetrahedron*.

Finally, following the plan adopted in the holoaxial class, the (*hkl*) form in the digonal polar is termed the *gyrotritetrahedron*.

The widespread plan of naming prisms, pyramids, etc., according to their "order" is arbitrary and meaningless, so prefixes are here preferred. Those suggested are *normo-*, for the forms the trace of which lies normal (perpendicular) to one of the lateral axes; *chordo-* for those the trace of which is the chord of the angle between the two lateral axes; and *clino-* for those the trace of which is inclined differently to the two axes.

Other novelties are the use of the prefix *duplo-* instead of the cumbersome adjective ditetragonal; the replacement of the face-shape name trapezohedron by a term analogous to those used in the Cubic system, namely *gyro-dipyramid*; and the corresponding change of scalenohedron to *duplo-disphenoid*.

The innovations suggested here are in part mere extensions of the Tetragonal ones, the prefix *normo-* thus designating forms the trace of which lies normal to a lateral axis and *chordo-* those the trace of which is the chord of the angle between two lateral axes. The proposals made in the Alternating subsystem, however, are so far-reaching as to require special discussion.

It is with considerable hesitation that a substitute is proposed for the term rhombohedron, yet in the interest of consistency that appears to be necessary. This term is based on face-shape, and in nature to find the form unmodified, and its faces of the theoretical rhombus outline, is highly exceptional. For the same reason, then, which leads to the rejection of cube, trapezohedron, etc., in favor of names based on face-number and arrangement, rhombohedron should be replaced by a corresponding term, the simplest appearing to be *ditrihedron*. The so-called scalenohedron,

HEXAGONAL SYSTEM

	Class	Representative	Symbol	Form-names	
				Undesirable	Proposed
	Hexagonal subsystem.				
D_6^h	Holosymmetric	beryl	*(00–1)*	base, basal pinacoid	pinacoid
			(11–0)	2nd order prism	normo-prism
			(10–0)	1st order prism	chordo-prism
			(hk–0)	dihexagonal prism	duplo-prism
			(hh–l)	2nd order dipyramid	normo-dipyramid
			(h0–l)	1st order dipyramid	chordo-dipyramid
			(hk–l)	dihexagonal dipyramid	duplo-dipyramid
C_6^v	Polar	iodyrite	*(00–1)*	pedion, "pinacoid"	monohedron
			(hh–l)	2nd order pyramid	normo-pyramid
			(h0–l)	1st order pyramid	chordo-pyramid
			(hk–l)	dihexagonal pyramid	duplo-pyramid
D_6	Holoaxial	high-quartz	*(hk–l)*	trapezohedron	gyro-dipyramid
C_6^h	Monoaxial	apatite	*(hk–0)*	3rd order prism	clino-prism
			(hk–l)	3rd order dipyramid	clino-dipyramid
C_6	Monoaxial-polar	nephelite	*(hk–l)*	3rd order pyramid	clino-pyramid
	Alternating subsystem.				
D_3^d	Alternating	calcite	*(h0–l)*	rhombohedron (1st ord.)	chordo-ditrihedron
			(hk–l)	scalenohedron	duplo-ditrihedron
C_3^i	Alternating-monoaxial	dolomite	*(hh–l)*	2nd order rhombohedron	normo-ditrihedron
			(hk–l)	3rd order rhombohedron	clino-ditrihedron

HEXAGONAL SYSTEM (*Continued*)

	CLASS	REPRESENTATIVE	SYM-BOL	FORM-NAMES	
				UNDESIRABLE	PROPOSED
	Pseudotrigonal subsystem.				
D_3^h	Ditrigonal	benitoite	(*10–0*)	1st trigonal prism	chordo-trigonoprism
			(*hk–0*)	ditrigonal prism	duplo-trigonoprism
			(*h0–l*)	1st trigonal dipyramid	chordo-trigonodipyramid
C_3^h	Trigonal-monoaxial	——	(*hk–l*)	ditrigonal dipyramid	duplo-trigonodipyramid
			(*hk–0*)	3rd trigonal prism	clino-trigonoprism
			(*hk–l*)	3rd trigonal dipyramid	clino-trigonodipyramid
	Trigonal subsystem.				
C_3^v	Ditrigonal-polar	tourmaline	(*h0–l*)	1st trigonal pyramid	chordo-trigonopyramid
D_3	Trigonal-holoaxial	quartz	(*hk–l*)	ditrigonal pyramid	duplo-trigonopyramid
			(*11–0*)	2nd trigonal prism	normo-trigonoprism
			(*hh–l*)	2nd trigonal dipyramid	normo-trigonodipyramid
			(*hk–l*)	trigonal trapezohedron	gyro-trigonodipyramid
C_3	Trigonal-monoaxial-polar	sodium periodate	(*hk–l*)	3rd trigonal pyramid	clino-trigonopyramid

RHOMBIC SYSTEM

	Class	Representative	Symbol	Form-names	
				Undesirable	Proposed
V_h	Holosymmetric	barite	(001)	basal pinacoid	basipinacoid
			(100)		macropinacoid
			(010)		brachypinacoid
			(hk0)		prism
			(h0l)	macrodome	macrodomoprism
			(0kl)	brachydome	brachydomoprism
			(hkl)		dipyramid
C_2^v	Polar	hemimorphite	(001)	pedion, "pinacoid"	basimonohedron
			(h0l)	macrodome	macrodihedron
			(0kl)	brachydome	brachydihedron
			(hkl)		pyramid
V	Holoaxial	epsomite	(hkl)	disphenoid	gyrodisphenoid

similarly objectionable, has two faces in place of each one of the "rhombohedron," and may appropriately be termed the *duplo-ditrihedron*.

When forms such as (*h0l*) and (*0kl*) are termed "domes," it is customary to explain to the student that a dome is interchangeable with a prism, upon re-orientation of the crystal. In making proposals for systematization of form-names, however, it is surely reasonable to require that all forms which are geometrically identical be given the same fundamental name. As (*hk0*), (*h0l*) and (*0kl*) are thus identical, it is here recommended that the term prism be applied to all of them. Prefixes may then be used to designate the position in which they chance to be held in a particular, arbitrary, orientation. Accordingly, (*h0l*), representing a prism held in macrodomal position for the time being, is termed a *macrodomoprism*; and other forms are treated correspondingly. In the polar class the (*h0l*) and (*0kl*) forms have but two faces each, and instead of complicating the names by a prefix *hemi-*, as often done, it is suggested that they be termed *dihedrons*, with appropriate prefixes to indicate their temporary positions. The holoaxial class in the Rhombic system corresponds to the gyroidal classes in preceding systems, and its general form is accordingly prefixed with *gyro*.

Following the same plan as in the Rhombic system, of using but a single fundamental term for all forms of like geometrical relations, the so-called orthodome must be named the *orthodomo-pinacoid*, the "clinodome" a *clinodomoprism*, and the "pyramid" a *pyramidoprism*. In other words, the root-word describes geometry, while prefixes designate the position in which a form chances to be held.

In the triclinic-holosymmetric class all the forms are geometrically pinacoids, and should be so-called, the prefixes indicating their respective positions; and in the asymmetric, all are monohedrons, and are designated similarly. This yields terms which contain a good many syllables, yet are so much more correct than those in common use as to seem preferable.

MONOCLINIC SYSTEM

	Class	Representative	Sym-bol	Form-names	
				Undesirable	Proposed
C_2^h	Holosymmetric	gypsum	(001)	basal pinacoid	basipinacoid
			(100)		orthopinacoid
			(010)		clinopinacoid
			(hk0)		prism
			(h0l)	orthodome	orthodomopinacoid
			(0kl)	clinodome	clinodomoprism
			(hkl)	pyramid	pyramidoprism
C_2	Holoaxial-polar	lithium sulfate	(010)	"clinopinacoid"	clinomonohedron
			(hk0)	hemiprism, "prism"	prismatidihedron
			(0kl)	hemiclinodome	clinodomodihedron
			(hkl)	hemipyramid	pyramidodihedron
C_1^h	Anaxial	clinohedrite	(001)	basal "pinacoid"	basimonohedron
			(100)	ortho "pinacoid"	orthomonohedron
			(h0l)	hemiorthodome	orthodomomonohedron

TRICLINIC SYSTEM

	Class	Representative	Symbol	Form-names	
				Undesirable	Proposed
S_2	Holosymmetric	chalcanthite	(*001*)	basal pinacoid	basipinacoid
			(*100*)		macropinacoid
			(*010*)		brachypinacoid
			(*hk0*)	"prism"	prismatipinacoid
			(*h0l*)	"macrodome"	macrodomopinacoid
			(*0kl*)	"brachydome"	brachydomopinacoid
			(*hkl*)	"pyramid"	pyramidopinacoid
C_1	Asymmetric	calcium thiosulfate	(*001*)	basal "pinacoid"	basimonohedron
			(*100*)	macro "pinacoid"	macromonohedron
			(*010*)	brachy "pinacoid"	brachymonohedron
			(*hk0*)	"prism"	prismatimonohedron
			(*h0l*)	"macrodome"	macrodomomonohedron
			(*0kl*)	"brachydome"	brachydomomonohedron
			(*hkl*)	"pyramid"	pyramidomonohedron

ARSENOFERRITE FROM JACHYMOV, CZECHOSLOVAKIA

William F. Foshag, *U. S. National Museum*,[1]
and
M. N. Short, *U. S. Geological Survey*.[1]

H. Baumhauer[2] has described small isometric crystals of a brown ferric arsenate from the Binnenthal in which the Fe:As ratio equaled 1:2. This mineral is believed to be pseudomorphous after an original arsenide of iron of the pyrite group to which he gave the name *arsenoferrite*. The mineral has not been found in its original unaltered state.

In the course of an examination of all available sulfides, one of us (M.N.S.) found a specimen of iron arsenide of distinctly isotropic character. This specimen (No. R-1063 of the Roebling collection, U. S. National Museum) came from the well known silver-nickel-cobalt-bismuth veins of Joachimsthal (now Jachymov) Czechoslovakia. Chemical investigation shows this mineral to be essentially an iron diarsenide with minor quantities of sulfur replacing arsenic and containing a small amount of copper. It therefore corresponds to the mineral described by Baumhauer and should be called *arsenoferrite*.

The Jachymov arsenoferrite occurs in the typical coarse cleavable white to pink carbonate gangue of this region. It forms irregular masses of very fine grain and rough conchoidal fracture. The color is a dull medium gray, less silvery than the gray of löllingite, but this variation is perhaps due to its fine grained nature. The luster is metallic to semi-metallic. There is no apparent cleavage present. The hardness is 5.5 and the specific gravity, determined with the pycnometer and corrected for the admixed carbonate shown in the analysis is 6.42.

The fresh massive mineral upon mineralographic examination proved to be exceptionally pure, no associated minerals other than veinlets of calcite being detected. This material was crushed and as much of the carbonates as possible removed by means of methylene iodide. The analysis, carried out by standard methods, gave the values given below.

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[1] Published with the permission of the Secretary of the Smithsonian Institution and the Director of the U. S. Geological Survey.

[2] *Zeit. Kryst.*, **51**, 143–145, 1912.

Analysis of Arsenoferrite from Jachymov.

W. F. Foshag, Analyst.

Fe	24.88	.446	
Cu	1.34	.027	.467
Pb	0.05	.000	
$CaCO_3$	4.00		
$MgCO_3$	1.57		
As	66.84	.891	.925
S	1.08	.034	
	99.76		

No cobalt or nickel could be detected. The analysis yields satisfactorily the ratios for $FeAs_2$ and the mineral is the arsenide member of the pyrite group.

The blowpipe characteristics are the same as for löllingite. Before the blowpipe it is infusible in the oxidizing flame, coloring the flame blue and giving off copious fumes with characteristic arsenic odor. Fusible in the reducing flame to a magnetic bead. In the open and closed tubes and on charcoal it gives the characteristic arsenic reactions. When examined under the reflecting microscope with polorized light the mineral is entirely isotropic in which it differs from löllingite, which is distinctly anisotropic. With HNO_3 it effervesces slowly, the surface staining brown. With $FeCl_3$ it stains brown. Negative reactions are obtained with HCl, KCN, KOH and $HgCl_2$. The mineral is undoubtedly an end member of the series (Co,Ni,Fe) As_2. The etch tests are practically identical with those of smaltite and the distinction can only be made by chemical tests.

The occurrence of isotropic iron diarsenide at Jachymov establishes arsenoferrite as a distinct species, differing from lollingite in its isotropic character. The absence of cobalt from this mineral, occurring as it does in ore deposits rich in cobalt minerals, is perhaps unusual but may be explained by the fact that two periods of mineralization have been recognized at Jachymov; an earlier one characterized by cobalt, nickel, bismuth and uranium associated for the most part with a siliceous gangue, and a later mineralization of chiefly silver in a carbonate gangue. While the relations of the arsenoferrite to these periods of mineralization is not now known it is possible that it belongs to the later period accompanying the silver.

PEGMATITE MINERALS OF ONTARIO AND QUEBEC

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INTRODUCTORY

Pegmatites occur over wide areas in Canada, and are of various types. They may be roughly classified according to their characteristic component minerals. A certain type may have a wide distribution, while another type may be distinctly regional. Thus, normal granite pegmatites (with minor modifications due to structure and mineral composition *e.g.* graphic granite, soda-rich feldspar dykes, potash-rich feldspar dykes, dykes either rich or poor in mica, etc.) occur abundantly throughout practically the entire region of the Pre-Cambrian crystalline rocks of eastern Canada, from Hudson strait and Labrador, in the east, to the Rainy river district, in western Ontario.

South of the St. Lawrence river, in Nova Scotia and New Brunswick, there occur what are probably small and strictly local distributions of tin- and tungsten-bearing pegmatites.

In the Ottawa region, throughout a broad belt stretching from the Lièvre river, in Quebec, nearly to Kingston, on Lake Ontario, is found an abundant series of dark-coloured, basic pyroxenite-pegmatites, which have been extensively mined for apatite and phlogopite mica.

In Renfrew and Haliburton counties, Ont., as well as at scattered outlying localities in the same general region, there occurs a series of molybdenite-bearing pegmatites (in part, pegmatitic quartz veins), which are probably of a distinct type.

In the Bancroft-Haliburton district, Ont., there is a local development of syenite pegmatites, which are characterized by a most interesting assemblage of minerals.

Further west, in southeastern Manitoba, there has lately been discovered an extensive series of lithium pegmatites, similar in their general character to those of the Black Hills, in South Dakota.

In British Columbia, throughout a belt known to extend from Fort Grahame, on the Finlay river, to the Big Bend of the Columbia river, a distance of over 300 miles, there is an extensive development of muscovite-bearing pegmatites, some of which have been worked in a small way for their mica content.

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[1] Published by permission of the Director, Mines Branch.

The above-mentioned pegmatites comprise some of the more distinct types recognized and will suffice to show the variety that exists. This paper is concerned only with (A) the normal granite pegmatites of Ontario and Quebec, upon which considerable mining has been done over a long period for either the feldspar or mica that they carry, and (B) the syenite pegmatites of the Wilberforce district, Ont. In an Appendix, however, there are also enumerated briefly the minerals that have been recorded from three of the other four types of pegmatites cited above.

Into Group A fall the greater number of the dykes, comprising the abundant, reddish feldspar-pegmatites of eastern Ontario and the adjacent portion of western Quebec; the less common, white or buff feldspar dykes of the same region and of eastern Quebec, north of the St. Lawrence river; and a few that may be styled freakish pegmatites, such as the lepidolite-bearing dyke in Wakefield township, Que., the peristerite-microcline dykes in Villeneuve and West Portland townships, Que., and the beryl pegmatite in Lyndoch township, Ont. These latter are of individual or strictly local occurrence.

Group B comprises the quartz-free dykes of the Bancroft-Wilberforce district, Ont., which are lithologically distinct from the normal granite pegmatites, and which, on account of their unusual and peculiar mineralization, it is convenient and desirable to consider as a distinct type.

The apatite-bearing pyroxene-feldspar dykes of Sebastopol and Brudenell townships, Ont., appear to be intermediate in type between acid pegmatites and the basic pyroxenite-pegmatites of the Ottawa district, but they probably are more akin to the latter and accordingly have not been included in this paper. They are famous for the large zircons, titanites and apatites with basal plane development that they have yielded.

It might, perhaps, be possible to sub-divide group A on the basis of certain more or less defined lithological differences, due, possibly, to differences in age, but such a division is beyond the scope of this paper. To be effective, also, such a classification would need to be supported by detailed microscopical examination and chemical analyses of the feldspars, coupled with close observation of the field relationships.

A. NORMAL GRANITE PEGMATITES

Description

The pegmatites examined by the writer occur throughout a region extending from a point on the north shore of the Gulf of St. Lawrence, north of Anticosti Island, in Quebec, to Sudbury, in Ontario, a distance of about 800 miles.

Various types of granite pegmatite occur throughout this region, and within limits, it may be said that certain types are peculiar to a district. That is to say, once one is familiar with the deposits, it is not difficult to identify, with a fair degree of accuracy, specimens of feldspar from the different major districts. It would not be so easy, however, to describe in words in what the identifying differences consist, these being largely a matter of experience.

In the great majority of instances, the dykes are found cutting gneiss, usually a rusty-weathering biotite gneiss, and this is often fairly heavily impregnated with small red garnets along the contacts. More rarely, the gneiss is tourmalinized with closely-packed, acicular crystals of schörl. The dykes usually exhibit tightly frozen contacts with the gneiss, though in some cases, a thin gouge selvage occurs and this then generally shows evidence of rock movement in the form of smooth, slickensided surfaces.

In only a few instances have quarries been opened on dykes cutting crystalline limestone. The feldspar of such dykes is usually white or grey-white, and lacks the fresh lustre of the more common pink or reddish microcline of the dykes cutting gneiss. It is also often characterized by a strong foetid odor of sulphuretted hydrogen, though this is not an invariable feature.

All the pegmatites are of Pre-Cambrian age, though in view of the rather wide dissimilarity in colour of feldspar, presence or absence of mica, tourmaline and other accessory minerals, it is probable that they were not all strictly contemporaneous. Studies on the age of the dykes, by the aid of determinations of the lead-uranium ratio in their radioactive minerals, have been made by Walker (22) and Ellsworth (8) (19) (23), the results indicating ages ranging from 120 to 1,293 millions of years. From these studies, the pegmatites of the Hybla district, Ont., appear to be among the youngest, while those of the Parry Sound district, Ont., the Villeneuve dyke, in Villeneuve township, Que., and the syenite pegmatites of the Wilberforce district, Ont., are among the oldest. In spite of these indicated wide age discrepancies, the writer has noted no instance of a dyke of one type cutting or intruding a dyke of another type, and therefore no grouping of the pegmatites on the basis of their relative age has been attempted. It may be noted, however, that the mica-apatite, pyroxenite-pegmatites of the Ottawa region are often cut by narrow stringers of granite pegmatite, which are thus indisputably younger than the basic dykes.

Broadly speaking, the dykes may be roughly classified according to the colour and character of their feldspar. The most common type is that in which the feldspar is microcline of a reddish cast, the colour ranging from a pale salmon-pink to brick red. This type of feldspar is widely distributed throughout the entire region from the Laurentian mountains to Georgian Bay, and constitutes the bulk of the commercial spar mined. Characteristic of these dykes is the extremely coarse crystallization of the feldspar, single individuals often measuring many feet, and forming large benches or ledges from which a large tonnage of spar can be won. In Sabine township, Ont., there occurs a remarkable example of such a dyke, in which the feldspar crystals, separated by quartz, attain a length of 30 feet and extend almost from wall to wall.

Dykes of white feldspar are less common. The individual crystals are usually much smaller than in the red dykes. The feldspar is usually microcline, though rarely it is albite or oligoclase, as in the case of a pegmatite in Aylwin township, Que. The white pegmatite at the Villeneuve mine, on the Lièvre river, Que., is composed of a coarse intergrowth of albite and white microcline.

There is a local development, also on the Lièvre river, Que., of dykes composed of a medium-textured buff microcline. This type of feldspar has not been noted elsewhere.

A few instances are known of dykes in which the feldspar is principally pale-coloured amazonite, as in Hull and Bouchette townships, Que. Local patches of amazonite also sometimes occur in the red pegmatites, as in Monteagle township, Ont., and in the beryl pegmatite in Lyndoch, Ont.

Most of the so-called microcline of the pegmatites is really perthite, the soda content seldom being much under 2 per cent and usually between 2 and 3 per cent. The perthitic structure is generally fairly coarse and easily discernible by the unaided eye.

Most of the pegmatites contain much quartz, usually in large, irregular masses between the feldspar and sometimes also in graphic intergrowth with the spar.

Vugs, or miarolitic cavities, are comparatively rare in the dykes, the constituent minerals of which are generally tightly frozen. Free, well-formed crystals of quartz, feldspar and other minerals characteristic of drusy pegmatites are therefore rather uncommon.

The dykes have yielded a considerable variety of the rare element minerals, including a number of new species. The Hybla district, in Ontario, is particularly rich in such minerals, other notable localities being the Mattawa, Sudbury and Parry Sound districts, also in Ontario, and the region north of the St. Lawrence, below Montreal, in Quebec.

The productive mica and feldspar pegmatites and their associated minerals have been described in a general way in three publications of the Mines Branch (18) (35).

ALBITE

(Oligoclase-Albite—Oligoclase.)

Small amounts of white or pale coloured, soda-rich feldspar are often encountered in the normal pink or reddish microcline pegmatites, usually as scattered crystals in the contact zones. Sometimes, the dykes carry a narrow band of such feldspar, a few inches wide, along the walls, as at the Gunter mine in Sabine township, Ont. At this locality, practically all of the visible mineral impurities in the dykes, in the shape of biotite and other dark, ferro-magnesian minerals, are confined to this wall zone, the dyke mass proper consisting of clean, pink microcline and quartz.

On the basis of chemical analysis of a number of such soda-rich feldspars from various pegmatites, it is apparent that many of them carry an important percentage of lime, and are therefore to be placed in the oligoclase-albite or oligoclase class. For the purposes of convenience, however, and since no microscopical examination of them has been made by the writer, the soda-rich feldspars have been included here under the general heading of albite. The following analyses of a number of such feldspars will serve to show the range of their lime-soda-potash ratio:

Locality	CaO	Na_2O	K_2O
McDougall township, Ont.	3.60	8.21	0.58
Monteagle " "	2.40	8.82	2.12
" " "	1.23	9.74	1.50
Conger " "	6.20	6.99	1.64
Bedford " "	4.20	8.26	2.42
Aylwin township, Que.	4.40	8.48	0.33
" " "	3.40	8.81	1.64
West Portland " "	1.60	8.90	1.68
" " " "	1.59	10.65	0.10
Villeneuve " "	1.20	9.87	1.08
Charlevoix county "	3.85	9.41	1.09

At the old Villeneuve mine, in Villeneuve township, Que., as well as at a small mine in the adjacent township of West Portland, a large portion of the dyke mass consists of white, lustrous albite of the peristerite variety, which exhibits a beautiful, light-blue schillerization. Through the albite are scattered irregularly masses of light cream-coloured microcline, for which the mine was formerly worked and which was in high demand for "dental spar." The dyke carries large amounts of black tourmaline, in stout prisms, and muscovite mica, as well as spessartite garnet, blue-grey apatite, gummite, occasional small zircons, uraninite and monazite. All these accessory minerals occur in the albite and seldom, if ever, in the microcline, the whole mineral association being in accord with the theory of Hess and Schaller (1) that such minerals have formed during albitization of an original microcline-pegmatite. The albite individuals are usually of small to medium size—seldom over 3 to 4 inches across—and often possess obscure crystal form. This type of dyke is of strictly local occurrence, and is confined to the area in question, only three or four outcrops being known.

Many of the normal pink or red microcline dykes of western Quebec and eastern Ontario probably carry minor amounts of soda-rich feldspar, particularly where such dykes contain appreciable quantities of mica, tourmaline or rare-earth minerals. It is often only by close examination of the feldspar surrounding such minerals that the twinning lines characteristic of the plagioclase feldspars can be distinguished in the field.

The platy, cleavelandite variety of albite is rare in the pegmatites of Ontario and Quebec, but certain of the dykes of the

Lake St. John district, in Quebec, contain it in quantity, as does also the beryl pegmatite in Lyndoch township, Ont.

Pale red peristerite occurs in some of the dykes of the Hybla district, Ont., and is very abundant in a pegmatite in Portland township, Ont.; the iridescence of the mineral from the last-named locality is often unusual, lively and attractive. The Hybla peristerite has been used by Parsons in a study of the cause of iridescence (12).

ALLANITE

Allanite is a not uncommon constituent of Canadian pegmatites, and some of the dykes contain it in fair abundance. It has been observed by the writer in quantity in certain of the red microcline dykes of the Parry Sound district, notably in the townships of Conger and McDougall; also in the township of Calvin, near Eau Claire; and at the McDonald mine in the township of Monteagle, near Hybla, all in Ontario.

At the last-named locality, it occurs locally in the dyke in very large masses, some of them weighing several hundred pounds. The Hybla allanite is black and coarsely-granular, with streaks of more massive, dense material running through it. In Conger, it forms large, platy crystals, 12 inches or more in length and up to 1 inch thick. In McDougall, the crystals are stouter and smaller. The Calvin allanite resembles that from Conger, is of a brown colour and is rather severely altered: it is associated with euxenite (polycrase?). Altered allanite is also found in some quantity in a dyke in the township of Henvey, Ont., where it occurs in small masses without crystal outline.

Walker and Parsons have described (5) allanite from Monteith township, Ont., and East Portland township, Que. Ellsworth mentions (13) its occurrence at the Wallingford mine, in Derry township, Que., where it is associated with uraninite, thucholite and cyrtolite, and also in a number of dykes in Butt township, Nipissing district, Ont. (19). In concession 6 of Butt, he observed allanite crystals up to 10 inches long. Obalski records (26) it in a mica-bearing dyke in Taché township, Lake St. John district, Que.

A highly-altered (chloritized), platy and loose-textured mineral, which accompanies the thucholite of a dyke in Henvey township Ont., and which is often impregnated with carbon, may be the pyrorthite variety of allanite.

AMAZONITE

(See microcline)

APATITE

Apatite is quite rare in the normal granite pegmatites of Ontario and Quebec. It occurs in minor amount as small greyish-blue crystals in the albite of the Villeneuve mine, Que., and is also reported from one or two of the old mica mines north of the St. Lawrence, below Montreal.

In a foetid feldspar dyke cutting crystalline limestone, near Perth, Ont., small pale-blue apatite prisms occur with titanite and emerald-green diopside. Ellsworth (23) mentions small (up to 2 inch) crystals of brown apatite in a dyke near Hybla, Ont. Small crystals, up to 3 inches long, of lustrous, green apatite also occur sparingly in a red feldspar dyke at the Purdy mine, in Calvin township, Ont.; the crystals are doubly-terminated and exhibit prominent development of the basal plane.

Apatite is stated (3) to occur in quartz pegmatites in Lacorne and Malartic townships, Abitibi district, Que., associated with molybdenite, fluorite, etc.

BERYL

Occasional small crystals of beryl are sometimes encountered in mica or feldspar mines in eastern Canada, but the mineral is in the nature of a rarity. At most of the recorded localities, the dykes are composed chiefly of white or light-coloured feldspar, and the writer has observed beryl in very few instances in dykes worked for red spar.

A little beryl, in small scattered crystals, has been reported from the old Villeneuve mine, on the Lièvre river, Que., and also from some of the old mica mines in Jonquière, Brassard and de Maisonneuve townships, north of the St. Lawrence, below Montreal (28) (29). In pegmatites opened up for molybdenite on the Kewagama river, in the Abitibi region of Quebec, beryl crystals up to 4 inches across are reported to have been found (30) (34).

There is only one recorded locality in eastern Canada where beryl occurs in quantity in a pegmatite dyke. This is in Lyndoch township, Ont., near the village of Quadville. The locality is an old one and has been described by Miller (2), Walker (3) and Ellsworth (10). The dyke, which is only about 10 feet wide, consists mainly of medium-textured, pale cleavelandite and peristerite, in which beryl crystals are abundantly distributed. The crystals range from thin, pencil-like prisms to individuals up to 5 inches across. The beryl is blue-green in colour, and is mostly flawed and cloudy, though the larger crystals sometimes yield small clear pieces of gem (aquamarine) quality. Small amounts of columbite, euxenite (var. lyndochite), fluorite, and amazonite accompany the beryl.

Beryl crystals up to 5 pounds in weight are stated (31) to have been found at old mica mines in Calvin township, near Mattawa, Ont.

BIOTITE

Biotite is one of the commonest minerals encountered in the pegmatites and is particularly abundant in those of the Parry Sound district, where few dykes are completely free of it. In this region, it commonly occurs in thin plates, often of large size, and is generally rather severely altered. Well-formed biotite crystals also occur in Dill township, near Sudbury, Ont.

In the dykes of the lower St. Lawrence, biotite and muscovite often occur in parallel intergrowth. Very interesting examples of such intergrowth are found at the Pied des Monts mica mine, near Murray Bay, Que., where crystals of muscovite sometimes enclose an inner crystal of biotite. From other crystals, sheets can be split that are half muscovite and half biotite, the line of demarcation being sharp and running diagonally across the sheet, while in others, biotite and muscovite occur in alternate layers. Kerr-Lawson has described (6) interesting pleochroic haloes in the biotite of this mine.

BISMUTHINITE

This mineral has been reported from the Lyndoch beryl pegmatite, in Ontario (10), where it is associated with small amounts of bismite, (55) and bismutite (53). It is also stated (32) to have been found in foliated, massive form in a dyke in Jonquière township, Chicoutimi county, Que.

Bismuthinite occurs in considerable quantity in the molybdenite-bearing quartz pegmatites of Lacorne and Malartic townships and the Kewagama lake region, Abitibi district, Que. (3) (30) (52).

CALCIOSAMARSKITE

A rare, lime-rich samarskite found originally at the Woodcox mine, near Hybla, Ont., and later in Conger township, near Parry Sound, Ont. (16).

The Hybla material occurred in a large mass in a dyke that has yielded an interesting variety of minerals including hatchettolite and columbite.

CALCITE

Calcite is not commonly regarded as a pegmatite mineral, but there seems to be little question that the calcite found in certain Canadian dykes is of primary origin (4) (23).

Calcite is not often found in the pegmatites, but at a few localities it is quite abundant. At the McDonald mine, near Hybla, Ont., a large mass of medium-grained, reddish calcite was encountered fairly near the surface and formed the matrix of disseminated ellsworthite, cyrtolite, titanite and smoky quartz. More remarkable still was the discovery, at about 80 feet below the surface, that the dyke, apparently over its entire width, changed into clean, massive calcite. This calcite is white to cream-coloured, breaks into large rhombohedral masses and is practically free of any admixed mineral. The normal pink microcline of the dyke gives way along the contact with the calcite mass to greenish-white albite. At several other spar mines in the vicinity of Hybla, small pocketty masses of calcite enclosed in microcline were observed, and in Portland township, north of Sydenham, Ont., calcite of an attractive reddish-orange colour occurs in a dyke containing large amounts of albite.

A white pegmatite cutting crystalline limestone in North Burgess township, Ont., also contains considerable calcite scattered through it (35).

CHRYSOBERYL

Evans has described (54) chrysoberyl from a pegmatite on the Post river, in Maskinonge county, Que. This is, apparently, the only recorded occurrence of the mineral in the granite pegmatites.

COLUMBITE

There are comparatively few recorded occurrences of columbite. It occurs probably in largest amount in the beryl pegmatite in

Lyndoch township, Ont., where it is found in thin, platy masses, often with hemispherical, radiating structure, in feldspar (2) (5). It also occurs massive in a narrow, pocketty veinlet in a pink feldspar dyke in Conger township, Ont., where it is associated with a brown, lustrous, resin-like mineral, not yet identified, that appears to be a decomposition product of the columbite. Walker and Parsons have described (5) fine-grained, massive columbite containing rutile from the Woodcox mine, near Hybla, Ont., and Ellsworth has described (9) a uranium-rich columbite occurring in small crystals and grains in a dyke in Dill township, Sudbury district, Ont., to which he has assigned the name toddite. What may be the same mineral was observed by the writer as a single, large, distorted crystal enclosed in a "book" of muscovite on a nearby lot in the same township.

Small amounts of a massive mineral resembling columbite have been noted by the writer in a dyke in West Portland township, Que., where it occurs with monazite and euxenite.

CYRTOLITE

(See zircon)

DIOPSIDE

Small amounts of diopside are occasionally found in the wall zones of pegmatites, particularly of dykes cutting crystalline limestone. It is evidently a contact mineral.

In a dyke cutting limestone in North Burgess township, near Perth, Ont., considerable diopside is present in stout prisms (35). The same dyke contains a small amount of a clear, emerald-green mineral, that is also possibly diopside; as well as small crystals of titanite, blue apatite, pyrite and pyrrhotite. Diopside also occurs in a dyke in Loughborough township, Ont. (4).

DUMORTIERITE

The only recorded occurrence of this mineral in a pegmatite is given by Walker, who describes it from a narrow dyke in Ashby township, Ont. (21). It is associated with cyanite, tourmaline and muscovite, and occurs in aggregates of slender prisms.

ELLSWORTHITE

Ellsworthite, a titanoniobate of uranium, lime and iron, is a distinctively Canadian mineral and was first described and named by Walker and Parsons in 1923 (5). It was found originally at the McDonald mine, near Hybla, in Monteagle township, Ont., and has later also been described (15) from Cardiff township, some miles to the west. It has not been recorded elsewhere.

The Hybla mineral is massive, and ranges from dark brown to amber yellow, both colours often being associated. Its occurrence was confined principally to a mass of salmon-coloured calcite which was encountered in the upper workings of the mine, and in which the mineral occurred in small, irregular masses and pellets. It is associated with cyrtolite, titanite and smoky quartz.

The Cardiff ellsworthite occurs in small crystals of rounded octahedral habit, and is found disseminated through the calcite filling of a pegmatite cavity.

EUXENITE

After, possibly, allanite, euxenite is the commonest and most widely-distributed of the rare element minerals found in the pegmatites.

It was first recorded (7) (60) in 1917 from a dyke in South Sherbrooke township, Ont., and has since been found at a number of other scattered localities.

In the South Sherbrooke pegmatite, the mineral was found in some quantity in a rather localized zone, and a small shipment of the ore was sent to the Mines Branch at Ottawa in 1919, in the hope that it might prove possible to concentrate it (19). However, no attempt at commercial production was ever made. A new analysis of the euxenite from this locality was made by Ellsworth in 1927 (8).

Other occurrences of euxenite in Ontario have been noted in Calvin, Mattawan, Sabine, Burwash, Henvey, Dill and Lyndoch townships.

The Mattawan mineral has been described by Ellsworth (9) as euxenite-polycrase.

The Lyndoch material, which occurs in well-formed crystals in contrast to the more usual massive form, has been described by Ellsworth (10) under the name of lyndochite. It is very much lower in uranium, and higher in columbium, than ordinary euxenite.

The Sabine euxenite has also been analyzed and described by Ellsworth (11).

In Henvey and Burwash, euxenite occurs in large, but rather rough, crystals. In Henvey, it is associated with cyrtolite.

Ellsworth has recorded (23) the occurrence in small amounts of a mineral of the euxenite family at the Watson mine, near Hybla, Ont.

In Quebec, traces of euxenite occur in several dykes in Hull township, and it also is found in some abundance in West Portland, where it is associated with monazite.

FERGUSONITE

Obalski mentions (26) (56) fergusonite as having been found at the old Maisonneuve mica mine, in Berthier county, Que. This appears to be the only recorded occurrence of the mineral in Canada.

FLUORITE

Fluorite is a comparatively rare mineral in all types of the granite pegmatites. Small amounts of finely-granular, purple fluorite occur in an amazonite dyke in Hull township, Que., and also at the Villeneuve mine, in Villeneuve township, Que., and the Leduc mine, in Wakefield township (25). Similar fluorite also occurs at the McDonald mine, near Hybla, Ont., and in the beryl pegmatite in Lyndoch township, Ont.

GADOLINITE

Gadolinite has not yet been identified with certainty from the Canadian pegmatites. A mineral resembling it occurs associated with cyrtolite in the Lyndoch beryl pegmatite, in Ontario, and the writer has also found small amounts of what may be gadolinite in a white, soda-rich feldspar dyke in Aylwin township, Que. Obalski mentions (26) the mineral as occurring at an old mica mine in Taché township, near Lake St. John, Que.

GALENA

Rare. A single mass, several pounds in weight, is stated to have been found in the McDonald dyke, near Hybla, Ont.

GARNET

Red almandite garnet is common, particularly in the wall zones of the dykes. Many of the pegmatites of the Mattawa-Sudbury region, Ont., contain an abundance of small, and often well-formed, almandite crystals along their contacts. Crystals up to 1 inch in diameter have been secured from dykes near Mattawa. Large crystals also occur in the Lyndoch beryl pegmatite, in Renfrew county.

In Quebec, large, misshapen crystals of red garnet occur in the dykes of the Saguenay region often enclosed in muscovite. At the Villeneuve mine, in Papineau county, and also in a similar dyke in the adjoining township of West Portland, red garnet occurs abundantly in the albite of the dykes and also as flattened crystals between the plates of muscovite. This garnet has an attractive, reddish-yellow wine colour and is probably spessartite.

GUMMITE

Small amounts of gummite are found at the Villeneuve mine, Que., where it is closely associated with uraninite, or represents completely altered uraninite. It is found principally as small, pellets of a brilliant orange-scarlet or yellow, massive mineral, or, in an altered form, as a grey, powdery incrustation. Both forms are common in small pits in the faces of large tourmaline crystals. It also occurs sparingly in a similar dyke in the adjoining township of West Portland, and at the Leduc mine, in Wakefield township (25).

HATCHETTOLITE

This rare columbate has been recorded only from the Woodcox and McDonald mines, near Hybla, Ont.

At the Woodcox mine, it occurs in irregular masses, associated with cyrtolite, calciosamarskite, columbite, etc. (5). At the McDonald mine, nearby, it occurs in small, nodular masses, intimately intergrown with titanite, and associated with cyrtolite.

HORNBLENDE

Hornblende crystals are often found in the wall zones of pegmatites cutting gneiss, and are sometimes of large size. They seldom possess good crystal outline and are difficult to free from the enclosing feldspar. Like the garnet and biotite often found in the feldspar and quartz of the dykes, adjacent to the walls, the hornblende is evidently a contact mineral, formed by action of the pegmatitic solutions on the country rock.

The hornblende is generally of a dark, greenish-black colour. The crystals often attain a length of 12 inches, or over, and may be 6 inches or more in diameter. Such large crystals are common in several dykes in Bathurst township, near Perth, Ont., and also at the McDonald mine, near Hybla, Ont.

HYBLITE

An alteration product of the uranothorite from the McDonald mine, near Hybla, Ont. It occurs as a thin, white or yellow coating upon the thorite crystals, and has not been found in sufficient quantity for quantitative analysis. By microchemical tests, Ellsworth (8) has determined both the white and yellow material to be hydrous, basic sulfo-silicates of thorium, and has termed the white variety alpha-hyblite and the yellow, beta-hyblite.

IRON (NATIVE)

Hoffmann has recorded (32) the occurrence in a kaolinized perthite from a pegmatite dyke in Cameron township, near Mattawa, Ont., of minute spherulitic grains of native iron, associated with fine, granular magnetite. An analysis of the grains yielded 90.45 per cent metallic iron.

LEPIDOLITE

Lepidolite is known to occur only in the dyke of the Leduc mine, in Wakefield township, Que., where it is the only mica present. It occurs in the form of large wedge-shaped crystals, or pyramidal crystal groups, sometimes one foot or more in diameter, associated with green and red tourmaline. The mica has a brownish colour, is cloudy and will not split into sheets, having what is known in the trade as "tangle-sheet" structure, due to imperfect crystallization (18).

The dyke here is in the nature of a freak pegmatite, being the only one of its kind known in a district in which normal granite pegmatites are numerous.

LYNDOCHITE

(See euxenite)

MAGNETITE

Magnetite is a fairly frequent mineral, usually in small scattered grains and sometimes massive: it is seldom found in large crystals. In the beryl pegmatite, in Lyndoch, Ont., magnetite is present in considerable amount, and some of the dykes in the Verona district, Ont., contain it in the form of scattered crystals.

MARCASITE

Less common than pyrite, but sometimes present in small amount. Probably of secondary origin.

Small amounts of marcasite, associated with pyrite and calcite, occur in the form of small balls in the cavities of a fracture zone cutting across a dyke in Henvey township, Ont.

MARTITE

Much of the apparent magnetite of the pegmatites is probably martite.

In Sabine township, Ont., it occurs (11) in nodular crystals up to 1 inch in diameter, and it is very abundant in some of the dykes in Calvin township, Ont. It has also been noted in dykes in Burwash township, south of Sudbury, Ont.

MICROCLINE

The predominant feldspar of the pegmatites is microcline-perthite, the soda content of which is seldom below 2 per cent, and averages about 2.5 per cent. Perthitic structures are usually plainly visible to the unaided eye and are often quite coarse. The colour is most commonly reddish, ranging from pale salmon-pink to brick-red. Some of the dykes carry microcline of a brownish-buff shade, while in others, the mineral has a mottled pinkish-buff or pinkish-green colour. White microcline is less common. A very high grade of white microcline occurs in the Villeneuve dyke, in Villeneuve township, Que., and was formerly in great demand for "dental spar." The microcline of dykes cutting crystalline limestone is sometimes of a blue-grey tone and is then often strongly foetid, probably due to the presence of occluded sulphuretted hydrogen. Such foetid microcline occurs in a dyke in North Burgess township, Ont. (35), and has also been described by Sine (4) from a pegmatite in Loughborough township, Ont. Sine suggests that the odour of the Loughborough mineral may be due to selenium sulphide.

Coarseness of crystallization is very variable. As a rule, the reddish microclines are the most coarsely crystalline, the feldspar individuals often forming large benches or ledges that sometimes run almost from wall to wall of the dykes, as at a locality in Sabine township, Ont., where the crystals measure nearly 30 feet in length. Such ledges, however, are often interrupted by quartz masses or stringers. At the Pedneaud mine, in Buckingham township, Que., well-formed, buff-coloured microcline individuals, up to 6 feet in length and 3 feet across, lie in a ground-mass of quartz, and very large crystals also occur similarly in a dyke in the adjoining township of Derry. From such large individuals, the crystals range in size down to those of dykes in which the average length is not much over a few inches, the rock then having the structure of an extremely coarse granite.

The microcline of different dykes varies considerably in its relative lustre and cleavability. The white varieties usually are comparatively dull and matt and do not break cleanly. Some of the buff microclines, and also the deeper red varieties, possess the best cleavage, breaking readily into blocks, and even into large, thin plates, with sharp edges. Some of these more brittle, glassy microclines (often termed 'crystal spar') make a large amount of quarry fines, due to shattering in mining. The buff-coloured, glassy microcline is often translucent in fairly thick plates and sometimes even transparent in plates up to $\frac{1}{8}$-inch in thickness.

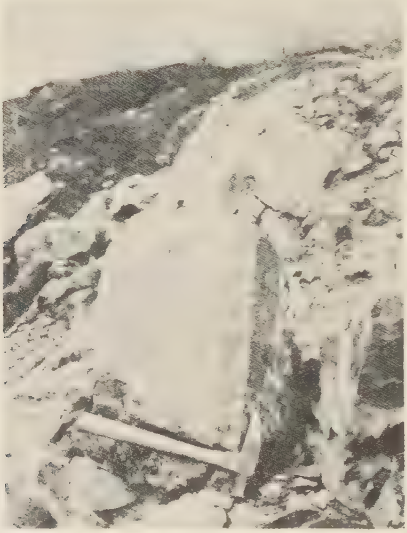


FIG. 1. Large crystal of red microcline from lot 1, concession 3, township of Burwash, Sudbury district, Ont.

The dykes being relatively free of vugs or cavities, well-formed microcline crystals are rare. Occasionally, however, large individuals having fairly good crystal outline have been observed

Such a crystal from a dyke in Burwash township, Ont., is illustrated in Fig. 1. In a pegmatite on the Hoffman property, in Portland township, Ont., there occurs an irregular, chimney-like, surface cavity, some 20 feet deep, the walls of which are lined with very large, partially-developed microcline crystals, some of which measure 2 feet in diameter (35).

Analyses by E. A. Thompson, Mines Branch Chemical Division, of three different, commercial microclines are given below:

	1	2	3
SiO_2	64.00	64.80	64.60
Al_2O_3	19.76	19.35	18.88
Fe_2O_3	0.06	0.05	0.32
MgO	—	0.11	—
Na_2O	1.81	2.29	2.96
K_2O	14.19	13.32	13.02
	99.82	99.92	99.78

1. Buff microcline (dental grade), O'Brien mine, Derry township, Que.
2. White microcline, Cameron mine, range IX, lot 27, Buckingham township, Que.
3. Pink microcline, McDonald mine, Hybla, Ont.

Amazonite is not common in the pegmatites. It is, however, present locally in the beryl-pegmatite in Lyndoch township, Ont., and also at the Woodcox mine, near Hybla, Ont., both of which localities have yielded large, platy blocks of a rich green colour. It also occurs in the Leduc lepidolite-pegmatite, in Wakefield township, Que. Pale amazonite constitutes the greater part of the feldspar in a dyke in Hull township, Que., and a pegmatite in Bouchette township, Que., is largely made up of amazonite graphic granite (35).

MOLYBDENITE

Molybdenite is not common in the normal granite pegmatites worked for mica or feldspar. It seems to be more abundant in the dykes of the region along the north shore of the lower St. Lawrence than elsewhere, particularly in those of the more easterly section, below Anticosti island. It usually occurs in the contact zones of the dykes, rather than within them. Ellsworth has noted it in small amount in Conger township, Ont. (13).

In northern Quebec, in La Corne, Malartic and Preissac townships (3), and around Kewagama lake (30) (52), molybdenite occurs in a rock described as quartz-pegmatite, associated with apatite, tourmaline, columbite, beryl and fluorite. Attempts have been made to work the deposits for their molybdenite content.

Many of the occurrences of molybdenite in Ontario and Quebec described as in, or associated with, pegmatites are actually in pyroxenic rock bordering pegmatite or coarse granite, and usually where such rock cuts limestone. In some cases, molybdenite occurs to a limited extent in the dykes, but usually only in the contact zones or on joints. It would appear that such dykes may logically be assigned to a distinct class of their own.

MONAZITE

Until recently, this mineral has only been recorded from the Villeneuve mine, in Villeneuve township, Que., where a nodular mass weighing about 12 pounds is reported (20) to have been found many years ago.

The writer has lately found an interesting occurrence of monazite in the adjoining township of West Portland. Here, monazite occurs in considerable amount in the form of large, well-formed, tabular crystals, sometimes as much as 6 inches in length by 3 inches across, associated with euxenite, allanite and large tourmaline crystals. A yellow mineral with resinous lustre, that has not yet been identified, is also present in small amount. The monazite possesses a brick-red colour, has a specific gravity of 5.12 and contains 23.75 P_2O_5.

MUSCOVITE

Many of the pegmatites carry muscovite mica, sometimes in large sheets, while others are practically free of it. In general, muscovite occurs in greatest quantity in the dykes composed of white or light-coloured feldspar, the red dykes usually carrying biotite, or being mica-free. However, some of the reddish pegmatites of the Sudbury district, Ont., contain large quantities of muscovite, and it also occurs in the dykes of the Parry Sound district.

Muscovite mica is not now mined in eastern Canada to any extent. Some thirty years ago, muscovite mining was carried on north of the St. Lawrence, in Quebec; in Villeneuve township, Que., and also at scattered localities in Ontario. The amount of merchantable mica recovered, however, did not prove sufficient to render mining profitable and operations have been abandoned (18). A little scrap muscovite is sometimes recovered at feldspar mines and sold for grinding purposes.

The Villeneuve mine formerly yielded very large sheets of muscovite, most of it stained and spotted, as is most of the mica from the dykes of eastern Canada.

Much of the muscovite found is what is termed in the trade "wedge mica," that is, the crystals taper towards one edge and yield sheets of unequal thickness, which are commercially worthless as sheet mica. Some of the dykes in Buckingham township, Que., yield muscovite of this type. Large quantities also occur in the pegmatites of Dill and Cleland townships, in the Sudbury district, Ont., sometimes accompanied by biotite, and the same association is found in Conger township, Parry Sound district, Ont.

PERISTERITE

(See albite)

PHENACITE

Small crystals of phenacite are reported (30) to accompany the beryl in a molybdenite-bearing quartz-pegmatite in the Kewagama river region, Abitibi district, Que. This is the only recorded occurrence of the mineral in Canada.

POLYCRASE

(See also euxenite)

Polycrase is stated (31) (45) to have been found many years ago, associated with beryl and xenotime, at a mica mine in Calvin township, near Mattawa, Ont.

PYRITE

Pyrite is often present in small grains in the pegmatites, particularly where much tourmaline occurs. It is usually associated with the quartz of the dykes, rather than with the feldspar; and where large segregated masses of quartz occur, pyrite—either massive or in crystals—is often present in considerable amount.

Pyrite occurs in quantity in a large, central quartz boss at the Richardson mine, in Bedford township, Ont. Large crystals and crystal groups of splendent pyrite occur scattered through the dyke at the O'Brien mine, in Derry township, Que., and in smaller amount at the Cameron mine, in Buckingham township, Que. Small, scattered pyrite crystals occur plentifully in a dyke cutting crystalline limestone in North Burgess township, Ont. (35).

PYRRHOTITE

Less abundant than pyrite, but of fairly common occurrence. It occurs in considerable amount, and in large masses, on the waste dump of the McDonald mine, near Hybla, Ont., and is also found on the adjacent Sutherland property (23). It is also present in quantity in a narrow, quartz-rich dyke in Derry township, Que., near the O'Brien mine. It has not been observed in crystals, all the occurrences noted being of compact, massive material.

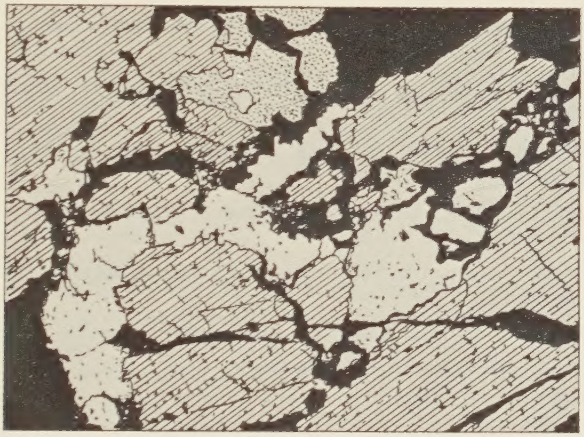
(*To be continued*)

NOTES AND NEWS

THE RELATION OF PYRITE TO WOLFRAMITE

F. N. GUILD, *University of Arizona.*

The microscopic study of polished surfaces of ores has emphasized the fact that pyrite is the first ore mineral to be deposited in the more common types of metalliferous veins. In some deposits, approaching what has been termed high temperature veins, it may be preceded by arsenopyrite, though the literature on polished surfaces seems to show some difference of opinion in this respect, some placing arsenopyrite later. In the samples studied by the writer, however, arsenopyrite is thought to be earlier than pyrite. Moreover Lindgren,[1] in a general discussion of gold-arsenopyrite deposits states that it is always the oldest deposited ore mineral. The other minerals included in his discussion were pyrite, chalcopyrite, pyrrhotite, zinc blende, galena, realgar and stibnite.



A tracing of a photomicrograph of polished surface from Las Guijas, Arizona, showing pyrite to be later than wolframite. Pyrite, white; wolframite, lined; quartz, dotted; holes, black. Some of the holes were formed in preparing the specimen (×30.)

The accompanying illustration is a tracing from a photograph of a polished specimen from the tungsten mines of Las Guijas, near Arivaca, Arizona, and about 50 miles south-west of Tucson. The ore is in white seams in granite, the predominating gangue mineral being pegmatite quartz. Some of these vein-dikes are intimately associated with very dark, in fact nearly black dikes of augitic minette. Considerable search is required to find specimens containing both pyrite and wolframite. A study of the illustration plainly shows pyrite to be later than the wolframite. This relation, however, is purely structural as there is no evidence that any reaction took place between the tungsten mineral and the pyrite. In fact the latter quite likely has replaced quartz which had previously replaced the tungsten mineral along the fractured surfaces of the wolframite.

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[1] Lindgren, *Mineral Deposits*, 3d Ed., p. 637, (quoting J. E. Spurr).

Minerals thought to be earlier than wolframite from a consideration of their zonal distribution or otherwise, are not easy to arrange in a satisfactory sequence as a result of microscopic work as it is difficult, or perhaps impossible, to find them associated with each other. Lindgren (*Mineral Deposits*, p. 744) states that cassiterite when accompanied with wolframite is apparently the earlier mineral. We may thus assume the following sequence to represent the order of deposition of a few of these higher temperature minerals: cassiterite-wolframite-arsenopyrite-pyrite.

NOMINATIONS FOR OFFICERS OF THE MINERALOGICAL SOCIETY OF AMERICA FOR 1931

The Council has nominated the following for officers of the Mineralogical Society of America for the year 1931:

PRESIDENT: Alexander H. Phillips, Princeton Uuniversity, Princeton, New Jersey.

VICE-PRESIDENT: William F. Foshag, United States National Museum, Washington, D. C.

SECRETARY: Frank R. Van Horn, Case School of Applied Science, Cleveland, Ohio.

TREASURER: Waldemar T. Schaller, United States Geological Survey, Washington, D. C.

EDITOR: Walter F. Hunt, University of Michigan, Ann Arbor, Michigan.

COUNCILOR (1931–1934): William S. Bayley, University of Illinois, Urbana, Illinois.

The eleventh annual meeting of the Society will be held December 29–31, 1930, at the University of Toronto, Toronto, Canada. It is planned to publish in the December issue of the Journal a *preliminary* list of titles of papers to be presented before the Society at its annual meeting. In order to appear on the advance program, titles of papers should be in the hands of the Secretary by *November 10*.

FRANK R. VAN HORN, *Secretary*

PROCEEDINGS OF SOCIETIES

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences, Philadelphia, May 6th, 1930.

A stated meeting of the Philadelphia Mineralogical Society was held on the above date with Mr. Toothaker presiding. Upon favorable recommendation of the Council, Mr. Henry Welkey was elected to membership. May 22nd was announced as the date of the annual exhibition of minerals by the Junior members of the Society, at North East High School.

Dr. Benjamin L. Miller, of Lehigh University, addressed the Society on "Minerals of Eastern Pennsylvania." He approached the subject from the geological side describing processes in the origin of various minerals and the location of deposits in the eastern part of the state. Many interesting references were made to localities familiar to members and which recalled numerous interesting and profitable trips of the past. The speaker, always a favorite with the Society, imparted a great deal of useful information in his usual pleasing and entertaining manner.

Mr. Cienkowski reported upon a trip to the Herkimer region of New York, having visited Little Falls, Middleville, Salisbury, Newport and Lionsville; at the last mentioned locality "box geodes" were obtained.

After an enthusiastic vote of thanks was tendered Dr. Miller the meeting adjourned with an attendance of 54.

LESTER W. STROCK, *Secretary*

Academy of Natural Sciences, Philadelphia, June 5th, 1930.

A stated meeting of the Philadelphia Mineralogical Society was held on the above date, Vice-President Biernbaum, presiding. Mr. Arthur H. Mason was elected to membership.

Mr. Samuel G. Gordon, the speaker of the evening, described briefly the Fourth Academy-Vaux expedition. Arriving at Mollendo, Peru, he crossed into Bolivia where considerable time was spent in collecting, then across Argentina to Buenos Aires and via steamer to Rio de Janeiro and Cape Town. His route now crossed what was formerly German Southwest Africa, Rhodesia, Union of South Africa, Belgian Congo and Tanganyika. From Daressalaam on the Indian Ocean, he embarked on a steamer for Marseilles, visiting Paris, London and other European cities before sailing for New York.

When in Bolivia he visited Araca, Chojnacota, Caracoles, Llallagua, Monserrat, Cerro Ubina, Tasna, Chorolque and Chocaya. The finds in Bolivia included many beautiful specimens of cassiterite, pyrite, teallite, aramayoite, wurtzite, vauxite, paravauxite, and metavauxite. In the Tsumeb copper mines, S.W. Africa, Mr. Gordon was most fortunate in discovering a vug of superb azurite crystals, on the 800 foot level, some of which measured 5 inches in length; here was also secured superior specimens of smithsonite, mimetite and cerussite. Visits to Abenab, Berg Aukis and Bobos yielded descloizite and calamine. At Grootfontein he visited the largest known meteorite about which a trench has been dug and which permits a close inspection of this immense mass of metal. He next spent some time at the Kimberly diamond mines, Pretoria, the Village Deep Gold mines near Johannesburg, the platinum mines near Potgietersrust, Bandolier Kop (fine corundum crystals), Louis Trichardt in the Transvaal, also the Chromium mines at Selukwe in Southern Rhodesia. At Broken Hill Mr. Gordon secured some beautifully crystallized tarbuttite, pyromorphite and calamine. He described also visits to Bwana, M'Kubwa and Roan Antelope and in the Belgian Congo he spent some time at the mines at Ruashi, Luishia, Likasi and Kambove. A large number of beautifully colored slides vividly illustrated the account of this memorable trip which has added many splendid specimens to the Academy's Mineral Collection.

Prize winners in the Junior Mineralogical exhibition held May 22nd, were announced as follows: Messrs. Ackoff, Bernheimer, Bradley, Breichner, Buscman, Day, Dornblum, Eichna, Fleming, Parish, Phillips and Wajtowicz. Mr. Parish, Junior President, thanked the Society for its co-operation and presented an honorary membership in the North East Mineralogical Club, to Mr. Charles R. Toothaker.

A rising vote of thanks was tendered Mr. Gordon for the excellent account of his long trip. The meeting adjourned with an attendance of 75.

Lester W. Strock, *Secretary*

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

Mineralogical Society, *June 3.*—Dr. L. J. Spencer: *A new meteoric iron from Piedade do Bagre, Minas Geraes, Brazil.* This mass, found in 1922 and weighing 130 lbs., is of special interest in showing on one corner a well-marked octahedral fracture, and on a polished and etched section taken from this portion of the mass a complex system of very distinct Neumann lines. Neumann lines are twin-lamellae produced by gliding on planes of the icositetrahedron (211); and it is believed that these, as well as the octahedral fracture, were developed by the shock of impact when the meteorite fell with its corner on hard rock.

Miss Jessie M. Sweet: *Notes on British barytes.* It is shown that the localities of barytes and fluorite follow the outcrop of the Whin Sill in the north of England and of the toadstones in Derbyshire. Attention is drawn to a change in colour from yellow to blue in some barytes crystals from the Mowbray mine, Frizington, Cumberland, on exposure to the light. Zoned crystals and some rare crystal-forms are described.

Mr. M. H. Hey: *On face- and zone-symbols referred to hexagonal axes.* The three hexagonal zone-symbols for any one zone referred to the Bravais axial system and obtained by cross multiplication of face-symbols dropping the first, second, or third index, all obey the Weiss zone-law and when added together applying a factor of 2/3 for the fourth index yield a four index zone-symbol indentical with that obtained for the zone from the gnomonic or linear projection. This four index zone-symbol also obeys the Weiss zone-law if a factor of 3/2 be applied to the unique index when operating upon the face-symbols of a face in the zone. General expressions are obtained for passing from any-one of the three index zone-symbols to the other two and also to the four index symbol and vice-versa.

Dr. L. J. Spencer: *Biographical notices of mineralogists recently deceased (fourth series).* For the past three years thirty eight biographies are included. Ages range from 32 to 91 years with an average of 68. Prominent are P. Groth and G. Tschermak, who both died in 1927.

Dr. F. Walker: *A tholeiitic phase of the quartz-dolerite magna of Central Scotland.* The tholeiites of Dalmeny and Kinkell are described and shown to contain chlorophasite. It is demonstrated by means of analyses and refractive index determinations that the residual glass is of acid composition in both rocks, a conclusion which does not support some of the ideas of Dr. C. M. Fenner on the crystallization of basalt.

Mr. M. H. Hey: *On pink epsomites and fauserite.* A supposed specimen of the latter in the British Museum proves to be pink epsomite. Fauserite is a doubtful species.

W. Campbell Smith, *General Secretary*